ASSESSMENT OF GROUNDWATER QUALITY IN INDUSTRIAL BELT OF FARIDABAD, HARYANA

A DISSERTATION

SUBMITTED IN THE PARTIAL FULFILMENT OF THE REQUIREMENTS

FOR THE AWARD OF DEGREE OF

MASTER OF TECHNOLOGY

IN

ENVIRONMENTAL ENGINEERING

Submitted by:

MRIDUL SHARMA

2K22/ENE/02

Under the supervision of

Prof. A.K. HARITASH

DEPARTMENT OF ENVIRONMENTAL ENGINEERING

DELHI TECHNOLOGICAL UNIVERSITY

(Formerly Delhi College of Engineering)

Bawana Road, Delhi-110042

MAY 2024

DELHI TECHNOLOGICAL UNIVERSITY
(Formerly Delhi College of Engineering)
Bawana Road, Delhi-110042

CANDIDATE'S DECLARATION

I, MRIDUL SHARMA, Roll No. 2K22/ENE/02 student of M. Tech (Environmental Engineering), hereby declare that the project Dissertation titled "Assessment of Groundwater Quality in Industrial Belt of Faridabad, Haryana" which is submitted by me to the Department of Environmental Engineering, Delhi Technological University, Delhi in partial fulfilment of the requirement for the award of the degree of Master of Technology, is original and not copied from any source without proper citation. This work has not previously formed the basis for the award of any Degree, Diploma Associateship, Fellowship or other similar title or recognition.

Place: New Delhi MRIDUL SHARMA
Date:

DEPARTMENT OF ENVIRONMENTAL ENGINEERING

DELHI TECHNOLOGICAL UNIVERSITY

(Formerly Delhi College of Engineering)

Bawana Road, Delhi-110042

CERTIFICATE

I hereby certify that the Project Dissertation titled "Assessment of Groundwater Quality in Industrial Belt of Faridabad, Haryana" which is submitted by **MRIDUL SHARMA, Roll No. 2K22/ENE/02**, Department of Environmental Engineering, Delhi Technological University, Delhi in partial fulfilment of the requirement for the award of the degree of Master of Technology, is a record of the project work carried out by the student under my supervision. To the best of my knowledge this work has not been submitted in part or full for any Degree or Diploma to this University or elsewhere.

Place: New Delhi **Prof. A.K. HARITASH**

Date: **SUPERVISOR**

PAPER NAME

2K22ENE02_Thesis Submission.docx

WORD COUNT	CHARACTER COUNT
15969 Words	**86941 Characters**
PAGE COUNT	FILE SIZE
61 Pages	**3.6MB**
SUBMISSION DATE	REPORT DATE
May 31, 2024 1:19 PM GMT+5:30	**May 31, 2024 1:21 PM GMT+5:30**

16% Overall Similarity

The combined total of all matches, including overlapping sources, for each database.

- 14% Internet database
- 5% Publications database
- Crossref database
- Crossref Posted Content database
- 12% Submitted Works database

Excluded from Similarity Report

- Bibliographic material
- Quoted material
- Cited material
- Small Matches (Less then 10 words)

ABSTRACT

The present study investigates the groundwater quality in Faridabad, Haryana, an industrial city in the northern part of India within the National Capital Region (NCR). The industrial town of Faridabad lies in the northern part of India and is currently undergoing speedy urbanization with high industrial growth in NCR. This has, coupled with its speedy urbanization and industrial development, led to impacts on groundwater resources within it. However, it's essential for drinking, irrigation, and industrial purposes. The present study involves essential water quality parameters like pH, total dissolved solids, total hardness, chloride, nitrate, sulphate, sodium, potassium, calcium, and magnesium for assessing the suitability of groundwater for irrigation and consumption. From the above data and interpretation, it will be enough to make a general suitability assessment for different water uses. With this, it can be observed that the pH in water at most places fall in the optimum scale, which could be presumed to state that neither water is too acidic nor alkaline. On the other hand, high levels of TDS at all indicative points reveal that water may have problems related to taste and long-term health issues. In most of the cases also indicate that total hardness and chloride exceed the desirable limits, which can lead to corrosion in pipes and have a salty taste. The nitrates were within permissible limits, but the sulphates, sodium, and potassium were within high concentrations in some of the locations and, therefore, reflective of the salinity of the soil and ensured health of crops. High levels of magnesium indicated probable ill effects on agricultural yield. It is thus essential to regularly monitor and treat groundwater for its sustainability. This further reinstates the need for effective practices and policies related to water management, which must prevent or at least minimize the adversities posed by groundwater contamination, hence saving people's health and well-being and the sustainability of agricultural practices in Faridabad.

Keywords: Groundwater Contamination, Water Resources, Physicochemical Assessment

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

INTRODUCTION

Water is termed as the lifeline of the biosphere. It is a universal solvent, dissolves different environmental pollutants, inorganic and organic chemicals. Natural resources comprise groundwater that works dynamically in nature and can be used as as substitute to the surface water for drinking, irrigation and the industrial usage (Arslan, 2000). One of the major consumers of groundwater is irrigational sector and it accounts for major annual withdrawal. There are several regions in which groundwater is considered as major source for meeting their demands while in certain areas, it acts as supplement to canals, well and other systems of irrigation. Groundwater in India is very much significant as approximately fifty percent of total irrigated region is dependent on groundwater. Moreover, approximately sixty percent production in irrigated food sector is dependent on well of groundwater (Shah et. al., 2000). Therefore, the contamination of groundwater has a direct link for spreading extensive variety of illness/disease to the human beings. It has been estimated that 1.2 billion population drink impure water which is the primary reason behind the occurrence of water linked diseases. It has been estimated that 1.2 billion population drink impure water which is the primary reason behind the occurrence of water linked diseases. Therefore, the concerns about issues related to quality of groundwater have grown (Rebolledo et. al., 2016) at global levels and consider these problems to be among the most important social, environmental and political issues (Nickson et. al., 2005; Azizullah et. al., 2011). Through dermal contact exposure pathways and drinking, groundwater can damage humans (Chidambaram et. al., 2015; Wu and Sun, 2016; Bhutiani et. al., 2016). Additionally, the most widespread environmental contaminants in the human World are heavy metals (Papatilippaki et. al., 2008). Contamination of resources of water by heavy metals is a grave environmental issue which unfavorably affects animals, plants and health of human beings (Rezania et. al., 2016).The constant contact between water and heavy metals leads to accretion of these metals in food chain and biota which in turn consequently enhances their intake by human. Long term exposure of heavy metals is associated with number of chronic harms and may results of grave hematological, anemia, mind harm and fault in kidney functioning (Sonayei et. al., 2009). The heavy metals like lead and cadmium are venomous even in extremely small doses. Metal Pb has an unenthusiastic manipulate upon the somatic enlargement and decreases the visual perception (Simeonov et. al., 2010). The inhalation of chromium (VI) is intended for bronchial asthma. The toxicity of manganese (Mn) disturbs the central nervous system, illustration response instance, hand control as well as the harmonization of eye and hand (Calkins, 2009). The foremost pathways of accomplishment of elements to aquifer are through soil-water interface. Since, the water moves in the course of the soil's profile, a diversity of substances which are water-soluble and get liberated from top soil (Pulikowski et. al., 2006).

The macro and alkali elements are majority of them. Zuane (1990) has affirmed that the kind and degree of chemical contamination of groundwater basically depend on the geochemistry encountered in soil, in the course of which the water makes its way earlier to become part of water bearing formations. Therefore, the absorption of trace elements in groundwater is directly influenced by the amount of particular heavy metals in soil. Further, the top soil is formed by weathering and erosional processes acting on rock. The amount of heavy metals in soil along with their blow upon bionetwork can be influenced by many factors such as the parent rock, weathering and anthropogenic actions. If the parent rocks have minerals containing high amount of trace metals, will unquestionably cause high concentration of trace elements in soil and water of that area. The metals resembling sodium and potassium are frequently associated with chloride and bromide. In these forms, they voluntarily dissolve in water. In soils containing considerable amounts of clay, these metals are not movable. Sodium and potassium are released slowly upon dissolution of rocks. The mobility of nickel in the soil increased by acid rain and thus accordingly in groundwater may raise the concentrations of nickel (International Program on Chemical Safety, 1991). The contamination of nitrate is primarily anthropogenic due to faecal material expulsion and use of fertilizers (Jat and Marc, 2016, 2018). Salinity may have various origins, but due to over exploitation of aquifer; the infiltration of brackish water in a fresh aquifer is the most frequent reason of high salinity.

Elemental arsenic is an infrequent mineral found in hydrothermal veins connected with ores of silver, cobalt and nickel. The weathering of rocks similar to granites may be an origin of arsenic infringement in soil and further in aquifers by penetration and percolation. Carbonate and bicarbonate are released by weathering of limestone and dolomite. The rise in chloride concentration in groundwater is caused by sedimentary rocks (evaporates) and a slight from igneous rocks. A variety of researches illustrated the harmful impacts of high concentration of elements like As, F, Zn, Pb, B, Al, nitrate, chlorides and phosphate etc. The concentration of these elements in many villages of area under study is found to be higher than permissible limit prescribed by BIS (Bureau of Indian Standards). It is consequently important to think about the underlying issues that causing the elevation of levels of certain elements in groundwater of study area and cases of certain health problems related to these elements. Consequently, the increasing pollution caused by heavy metals in food chain become the blazing question in current time due to their impending buildup in eco-system in the course of polluted soil, water and atmosphere (Begum et. al., 2009). As an outcome of long time function of weathering and erosional processes, the heavy metals can gathered in the soils to venomous levels. The most important factor that serves as a quality index for water is pH (Bhadja et. al., 2013). Soil irrigated by means of waste water build up heavy metals in surface soils and when the competence to preserve heavy metals is reduced due to frequent application of contaminated water, heavy metals percolate into groundwater or soil solution accessible for plant uptake (Papatilippaki et. al., 2008). Both the pollution and environmental degradation caused by heavy metals is a hazard to environment and is a matter of grave concern (Ali et. al., 2013, Hashem et. al., 2017). Trace metals are persistent in environment by virtue to their toxic contamination in food chains, and hence cause health tribulations. The constant exposure to heavy metals in the surroundings is a threat to lives (Wieczorek- Dąbrowska et. al., 2013). The concentrations of metals exceeding threshold point diminish the soil fertility by influencing the microbiological equilibrium of soils (Barbieri, 2016).

The conclusion of research findings point out that occurrence of trace elements in groundwater is directly influenced by the concentration of particular metal in soil. The noteworthy natural environmental changes and human activities collectively are two governing forces that are responsible for variability of quality of groundwater (Li, 2014). In natural system, the geology of any area particularly the rock types are the significant aspect which has an impact on the quality of groundwater. As, Tosham area consists of different rocks which acts as pathways for water when it percolates down. The geochemistry of such rocks alters the quality of groundwater by adding their elements to it. Tosham in Haryana has similar rock representative to Barmer, Jodhpur, Nakora, Jalor, pali, Siwana and Jaisalmer in Rajasthan (Fig. 1.1) (Kochhar, 1984; Sharma and Kumar, 2017). Moreover, the rocks of all these places are well known for their trace elements concentration and these rocks are considered as the part of Malani Igneous Suit (MIS) (Kochhar, 1973, 1983, 1984, 2000; Eby and Kochhar, 1992; Pareek, 1981; Bhushan, 2000; Kumar et.al., 2019). The communications of heavy metals with different groups of organisms are complex to a large extent (Chalkiadaki et. al., 2014). Water scarcity and contamination of the available water sources are evident in numerous regions of the developing countries (Muhammad et. al., 2017). Toxic trace metals cause a significant risk to both terrestrial and marine ecosystems (Slaveykova et. al., 2018). The heavy metals after releasing from both natural resources and human activities degrade the sediments, soils and natural water bodies. Heavy metals once released into the atmosphere come back to the land and result into depletion of quality of water and soils. They either trickle down into groundwater or gathered in biota due to their persistent nature.

1.1. WATER RESOURCES (INDIA)

Water is a essential resource, covering about 71% of the Earth's surface, but freshwater constitutes only around 3% of this total. India, with 2.45% of the world's surface area, holds 4% of global water resources and supports about 16% of the world's population. Annually, India receives approximately 4,000 cubic km of water from precipitation, with an average precipitation of 1170 mm per year. The total available surface water and replenishable groundwater is 1,869 cubic km, but only 60% of this, or 1,122 cubic km, is utilizable.

India's surface water resources include rivers, lakes, ponds, and tanks, with an estimated mean annual flow of 1,869 cubic km in all river basins. However, only about 690 cubic km, or 37%, of the surface water is usable due to seasonal flow variations and limited suitable storage sites. Over 90% of the annual flow of Himalayan rivers occurs within a four-month period, complicating resource capture and storage.

Groundwater resources in India are approximately 432 cubic km, with the Ganga and Brahmaputra basins holding about 46% of these resources. High groundwater utilization is observed in the north-western river basins and parts of southern India, especially in Punjab, Haryana, Rajasthan, and Tamil Nadu. In contrast, states like Chhattisgarh, Odisha, and Kerala utilize a smaller proportion of their groundwater potential. Groundwater accounts for over 50% of the irrigated area in India, with about 20 million tube wells installed. India has constructed nearly 5,000 major or medium dams and barrages to store river water and recharge groundwater.

Agriculture is the primary user of both surface and groundwater, consuming 89% of surface water and 92% of groundwater. The industrial sector uses 2% of surface water and 5% of groundwater, while the domestic sector accounts for 9% of surface water use, higher than its groundwater use.

1.1.GROUNDWATER CONTAMINATION IN INDIA

Groundwater of India is primarily of calcium bicarbonate and mixed type. But there are many places in India where other types of water like sodium chloride type are also exist. The quality of aquifers changes from place to place. Groundwater quality of India in shallow aquifers is commonly appropriate for different purposes. Groundwater has turn into the most vital resource of water used for farming, households as well as engineering sectors of several nations. A major portion of population (85%) of India resides in rural regions and depends upon the groundwater assets for fulfilment of their daily requirements. Furthermore, nearly about 50–80 % of the land is irrigated by groundwater (Raju, 1998). Groundwater contamination in India has raised alarming situation in recent times. The hasty development of industries and extension of big towns compel a high stress upon water wealth together with groundwater resources which frequently results in their deterioration as well as contamination.

In India like emergent nations roughly eighty percent of the entire diseases have directly link with the deprived drinking water quality (Olajire and Imeokparia, 2001).West Bengal, Bihar and Uttar Pradesh (Eastern regions of the country) have the elevated iron concentration in groundwater (Krishnan et. al., 2017). The tracts of vast area in various states like Gujarat, Rajasthan and Andhra Pradesh are exaggerated by groundwater having concentrations of fluoride more than 1 mg/l. Primary source of contaminants in sediments are mainly the rocks of aquifers and its concentration varies with the nature of formation. Estimates hit upon that sixty five percent of villages of India are open to fluoride risk. A number of districts covering area around 88,688 km2 and 50 million of population in some Indian states, namely, Uttar Pradesh, Jharkhand, Assam, Chhattisgarh and Bihar have been reported under the exposure of arsenic contamination in groundwater possessing value more than 50 μg/l (NIH & CGWB, 2010).

The six million kids which are lower than the age of 14 years, out of nearly 66.62 million people from 18 states, namely, Karnataka, Jharkhand, Uttar Pradesh, Kerala, Madhya Pradesh, Jammu & Kashmir, Andhra Pradesh, Assam, Chhattisgarh, Delhi, Haryana, Maharashtra, Punjab, West Bengal, Orissa, Rajasthan, Tamil Nadu and Gujarat have been reported to have fluoride contaminated groundwater. Depth of groundwater table is also concerned as a reason for groundwater contamination. For example, in Vishakhapatnam, high value of fluoride is found in groundwater exist at shallow depth lesser than 15m (Rao et. al., 1998) while in Mehsana region of Gujarat, high fluoride concentration is found in aquifer layers deeper than 100m in depth. The high fluoride concentration in groundwater is also exhibited by smaller regions of a number of states like Punjab, Karnataka, Utter Pradesh, Madhya Pradesh and Maharashtra. The sediments of the Alluvial Indo-Gangetic-Brahmaputra basins primarily have the high arsenic content (greater than 0.05 mg/l) (Chowdhury et. al., 1999). The water with high arsenic concentration was noted initially only in West Bengal and Bangladesh, but at the present, the contaminant is also reported from Assam, Punjab and Nepal to different regions of Pakistan.

The contamination is frequently restricted to the Indo-Ganga-Bramhaputra alluvial topography covering areas of Punjab, Uttar Pradesh, Assam, West Bengal, Manipur, Bihar and Haryana (Saha, 2009; Saha et. al., 2009; Sahu and Saha, 2015). The considerable instances of elevated arsenic concentration have also been reported from the mineralized zones of hard rock regions of Chhattisgarh, (Mukherjee et. al., 2014).

Salinity does not cause rigorous health effects as compared to fluoride or arsenic. Moreover, salinity can be generally classified into costal salinity and inland salinity based on its origin. The former salinity is caused by intrusion of saline water and later due to interaction of water with rocks encountered. Inland salinity is found in the of Rajasthan, Madhya Pradesh, Gujarat, Punjab, Haryana, Maharashtra, Uttar Pradesh and in large range of pockets of some other states (Krishnan et. al., 2017). It has also been reported from the central part of country such as Chhattisgarh that inland salinity is origined by high amount of sulphate in groundwater (Central Groundwater Water Board, 2006). In coastal areas, due to over pumping, the salinity is caused by saline- water intrusion and has been reported from Gujarat, West Bengal, Odisha, Andhra Pradesh and Tamil Nadu (CGWB, 2014b, c). Besides, in low lying coastal regions, infiltration of sea-water during storm or high tide episode also contributes to the salinity of groundwater. Salinity has been observed almost in all major aquifer systems but primarily confined with granite alluvium, shale, schist and also in limestone and Deccan Traps. The parts of Andhra Pradesh, Orissa, West Bengal, Saurashtra and Kutch regions of Gujarat exhibit the intrusion of ocean water into coastal aquifers. The concentration of arsenic, lead, nickel, zinc and chromium have been observed to be above their respective harmless limits specified by WHO in lots of villages of South- West Punjab (Bajwa et. al., 2017). In several parts of the India, the increased application of nitrogenous fertilizers resulted into nitrate contamination of aquifers at levels higher than 40mg/l (Agrawal et. al., 1999). Moreover, there are several areas of the country have been manifested to have aquifers contamination by means of manufacturing chemicals. These include the town and areas where industrial projects are often situated. Some prominent examples are Patencheru (Hyderabad), Behala (Kolkata), Ankleshwar (South Gujarat) and Tiruppur (Tamil Nadu) (Krishnan et. al., 2017). Nearly about two lakh km2 region has been anticipated to be exaggerated by saline water having electrical conductivity (EC) in of 4000 μS/cm. Presently, a number of regions in Southern Haryana and Rajasthan where the value of

EC in groundwater is more than 10000 µS /cm and thus making water unhealthy for consumption (CGWB, 2014). Along with these, in recent reports of Kolkata and additionally in cities like Kanpur and South Gujarat, there are plentiful instances where originated wastes from underdeveloped mechanized units are thrown in channels which are unlined or discarded straight forwardly in bore wells. Furthermore, this nationwide picture of groundwater quality is still distant from comprehensive reality and may be alarming if constant efforts to monitor water quality of aquifer are not enhanced. The stations that are used for monitoring are bare and scattered. The numerous agencies do not have harmonization nor did they coordinate well with each other.

1.2.HYDROMETEOROLOGY AND HYDROGEOLOGY OF STUDY AREA

Haryana primarily receives rainfall during the monsoon of Southwestern origin. The average yearly rainfall varies from more than 862 mm in the North-Eastern region that bordering Himachal Pradesh near hills of Siwalik and as little as 313 mm in the regions of South-Western region that bordering Rajasthan. In more than fifty percent of area of the state, the average rainfall is less than 500 mm. The showers of winter are quite widespread. Rainfall gradually decreases towards Southwest and Southern districts. Higher aridity is observed in S-W regions of the Haryana that border the state, Rajasthan. In Rewari, Mahendragarh, Sirsa, Hisar and Bhiwani, drought conditions are frequent. Both summer and winter are experienced by the state. During the months of December and January, winter frost is common. The maximum wind speed recorded is 5.3 km per hour and minimum is 0.4 km per hour. 2.9 km per hour is the average wind speed in Haryana (GWYB, 2016-2017). The mean yearly average relative humidity of state is noted as 60%. It ranges from 30% (April) to 90% (August). Moreover, the climate of Bhiwani could be categorized as semi-arid, tropical steppe, warm and have cold as well as dry winter with extremely hot summer. In a year, there are four seasons in the state. From the mid of March, the warm season starts and remains in the state up to month of June (last week). The warm season is followed by the South-West monsoon. Transition period is formed by post-monsoon season from September to October. The usual annual rainfall is disproportionately scattered over 22 days and is nearly about 420 mm. Both July and August are the wettest months. From last week of June, the South-West monsoon sets in and leaves the state in end of September. It contributes nearly 85% of yearly rainfall. The remaining of 15% of rainfall is contributed by Western disturbances and thunder storms during non-monsoon period (GWYB, 2016-2017). From Southwest to Northeast, there is increase of rainfall in the district Bhiwani. However, the nature of climate of Haryana is semi-arid to sub tropical. On the basis of groundwater movement as well as surface drainage pattern and geohydrological conditions.

1.3.WATER LEVEL FLUCTUATIONS

To know the trend in fluctuations of water level, annual fluctuations, seasonal 34 fluctuations and long terms fluctuations in area under study, the data related to depth of water level is taken from groundwater yearbook of respective years published by CGWB. During May 2018 and January 2019, the depth to water level in Haryana varies from 0.74m bgl (Rohtak) to 100m bgl (Mahendragarh) and 0.20 m bgl (Bhiwani) to 86m bgl (Mahendragarh) respectively (Fig. 3.1). The area under study has depth of water level in pre and post monsoon in year 2018 are 6.25m bgl and 4.63m bgl respectively exhibiting the effect of recharge due to precipitation.

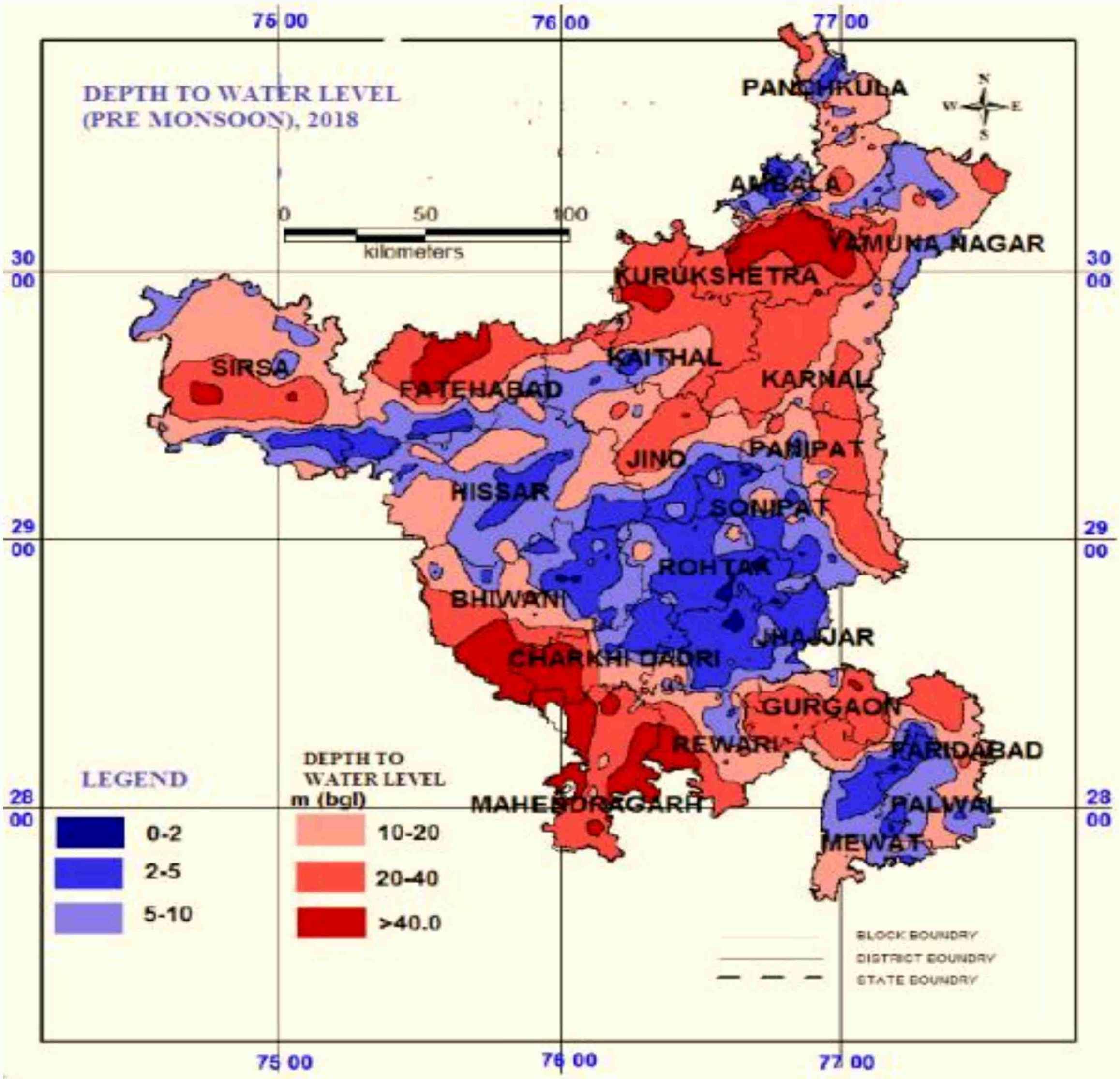


Figure 1 Depth to water level in Haryana (Pre-Monsoon), 2018 (GWYB, 2018-2019)

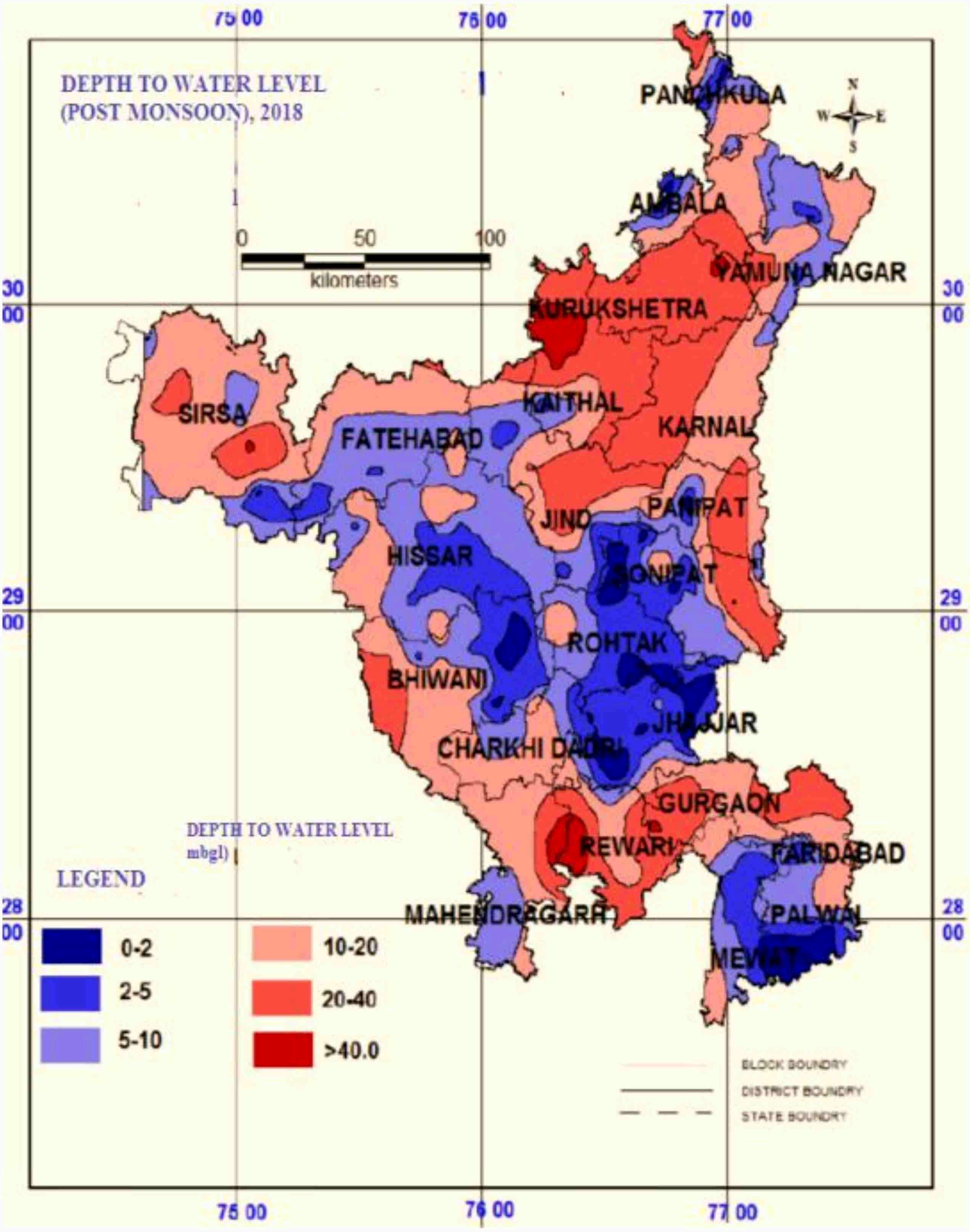


Figure 2(b) Depth to water level in Haryana (Post monsoon), 2018 (GWYB, 2018-2019)

LITERATURE REVIEW

Groundwater plays a vital role in the Delhi National Capital Region as it supports various uses, from drinking to agriculture. For the last couple of years, the region has witnessed a high rapid rate of urbanization accompanied by fast industrial growth and the intensification of agriculture, all of which add to the concern about the quality of groundwater in this region. Groundwater quality is a function of a complex interplay of natural geological formation besides anthropogenic activities, industrial discharge, and agriculture runoff with the interchange of urban wastes. These parameters are usually pH, electrical conductivity, total dissolved solids, chloride, fluoride, nitrite, nitrate, alkalinity hardness, and anions. Work has been presented from the available literature in this respect on the quality of groundwater in Delhi NCR, especially about those critical parameters and to the methodologies used for management, monitoring, and modelling of water quality. In this respect, some works consider the advanced application of such statistical methodologies and GIS in the groundwater quality assessment, and some other works deal with the determination of general groundwater quality as a matter of concern in the areas under study. Groundwater quality is an important criterion not only for public health but also for agriculture in terms of productivity. Groundwaters of lousy quality may cause several health issues as well as the dropping down of agriculture yields. Many studies were determined that the chemical composition of groundwaters is characterized as very important in the determination of their suitability for different uses. For example, high values of both fluorides and nitrates may be accountable for umpteen health-related problems, while elevated levels of TDS and hardness may have adverse effects on crop productivity and soil health (Kumar & Singh, 2010; Gupta et al., 2015). Having a high population density further moves those problems related to groundwater quality in most of the areas of Delhi NCR that are also primarily agrarian. This must be so since the groundwater quality is very heterogeneous due to natural factors, natural factors combined with the geologic formation of the region, and anthropogenic activities. There is thus a need to study the characteristics and their influences and devise proper strategies for water management. The groundwater quality is related to the quality of the river water; the latter is the recharging source for most aquifers. For the proper management of river water quality, it is necessary to perform competent monitoring and control about the discharge of polluting substances from the industry or from the run-off and waste of urban or agricultural sources. Of course, the major rivers, like Yamuna, in the Delhi NCR, also recharge the ground water, but then these rivers are highly contaminated and thus have a direct effect on the groundwater also (Sharma and Kansal, 2011). Some of the ways to fight the quality of the river water are to control industrial effluents strictly through regulations, implement sustainable agriculture, and efficiently run urban waste management systems. It is effective river water quality management, which adequately improves groundwater quality parameters of the territory.

Water quality monitoring is one of the most essential tools to ascertain whether the groundwater resources are healthy or not. Besides, water samples must be obtained carefully and analyzed at predictable intervals to measure multiple physical, chemical, and biological features. Continuous monitoring helps in the identification of sources of pollution and how well the practices adopted about management are done to ensure that ecological procedures are followed as per the standards provided by the regulatory bodies. Many studies have been carried out to monitor the groundwater quality in the Delhi NCR area. For instance, a thorough investigation of the groundwater quality of the Lower Varuna River Basin conducted by Raju et al. (2017) revealed that many of the water quality parameters would be highly variable in both space and time. Continuous monitoring of this kind of groundwater resource could significantly boost management. Monitoring water quality within the basin is a necessary process for the estimation of the health level of the groundwater resource. Criteria for the measurement of a lot of physical, chemical, and biological parameters are based on the collection of water samples and their analysis, which is done regularly. This kind of approach allows for the identification of the sources of pollution, the effectiveness of the management practices, and the meeting of the set regulations. In the Delhi NCR, there are many studies concerned with studies on monitoring the quality of the groundwater. For instance, comprehensive work was done by Raju et al., 2017, on the quality of groundwater in the Lower Varuna River Basin. It was shown from their study that there exists a tremendous change in space and time in the water quality parameters. The groundwater resource can be managed, therefore, if continuously monitored.

To demonstrate the groundwater measures and its suitability for drinking, irrigation and major contaminant source have been carried out all over the world (Adimalla and Venkatayogi, 2018; Adimalla et al., 2018b; Dişli, 2017; Li et al., 2016b; Vahab et al., 2015). Faten et al. (2016) observed that the water rock interaction and evaporation are the main source for contaminating groundwater in Northeastern, Tunisia. Li et al. (2016a) noted that the groundwater evaporation influences the development of sulphate-type groundwater contamination in a Semi-arid Region of Northwest China. Sadat-Noori et al. (2014) evaluated an aquifer with the combined use of the Water Quality Index (WQI) and a geographical information system (GIS) in a semi-arid area at Iran. The GIS technology often used for generating the spatial distribution maps of groundwater quality for various purposes, and it can also helpful to identify the water quality zones and also polluted zones (Jasrotia et al., 2018, 2019; Adimalla and Taloor, 2020).

However, over exploitation of groundwater is one of the biggest problem in many regions of the world. Moreover, India is also one of them. NGWA (2016) noticed that the annual extraction of groundwater in India is the highest in the world, which even supersedes that of the USA and China put together. Furthermore, according to the Central Ground Water Board (CGWB, 2014) report reveals that the groundwater draft in India is ~245 × 109 m3, most of which is used for irrigation purposes only and also nearly 90% of rural population of the country uses groundwater for drinking and domestic purposes. However, in India, growing urbanization, population growth, and over exploitation of rural areas for drinking, domestic and agriculture needs, extreme usages of fertilizers, impacts of anthropogenic activities, etc., which majorly influence the groundwater quality. Therefore, a number of studies on groundwater quality with respect to drinking and irrigation purposes have been carried out in the different parts of India (Haritash et al., 2017; Rajesh et al., 2012; Adimalla and Venkatayogi, 2017, 2018; Narsimha and Sudarshan, 2013; 2017a, 2017b; 2018a, 2018b; Adimalla and Li, 2019; Narsimha et al., 2018; Chetan and Ahada, 2017; Narsimha, 2018; Subba Rao et al., 2012). In the present study (Chinnakodur) area, most of the population purely depend on groundwater, which is only the main source for drinking and irrigation purposes. The predicament of Medak region/district, Telangana is caused for much concern, considering the steady drop of water table from 18.39 m below ground level (mbgl) to 24.34 mbgl (Adimalla et al., 2018b), and Chinnkodur is one of the regions facing the groundwater scarcity, contamination/pollution, decline of water and quality issues.

1.4.DETAILED ANALYSIS OF GROUNDWATER QUALITY PARAMETERS

1.4.1. CHARACTERIZATION OF PARAMETERS IN THE STUDY AREA

pH is a measure of the acidity or alkalinity of water, with a recommended range of 6.5 to 8.5 for drinking water (WHO, 2017). Studies in the Delhi NCR have reported pH values within this range, although localized deviations have been observed, particularly in industrial areas where acidifying pollutants are present (Kumar et al., 2018). Maintaining an appropriate pH level is crucial for the palatability of water and for preventing corrosion in water distribution systems.EC measures the water's ability to conduct electrical current, which is directly related to the concentration of dissolved ions. High EC values can indicate the presence of high levels of dissolved salts, which can be detrimental to both drinking water quality and soil health (Singh & Kumar, 2016). In the Delhi NCR, EC values have varied significantly, often exceeding the permissible limits for drinking water (BIS, 2012). High EC levels are commonly associated with areas receiving industrial Total Dissolved Solids (TDS) represents the total concentration of dissolved substances in water. The Bureau of Indian Standards (BIS) sets the acceptable limit for TDS in drinking water at 500 mg/L (BIS, 2012). Research indicates that TDS levels in many areas of Delhi NCR exceed this limit, raising concerns about water quality (Raju et al., 2017). Elevated TDS levels can affect the taste of water and lead to health issues such as kidney stones and hypertension.Chloride is a common anion in groundwater, originating from both natural sources and anthropogenic activities such as sewage discharge. High chloride concentrations can impart a salty taste to water and cause corrosion in pipes (WHO, 2017). Studies in Delhi NCR report chloride levels often above the acceptable limit of 250 mg/L, particularly in industrial zones (Gupta et al., 2015). High chloride levels can also indicate contamination from sewage and industrial effluents.Fluoride in groundwater primarily originates from geological sources. While low levels of fluoride are beneficial for dental health, concentrations above 1.5 mg/L can cause dental and skeletal fluorosis (WHO, 2017). Investigations in Delhi NCR reveal significant spatial variability in fluoride levels, with some areas showing concentrations above the recommended limits (Ayoob & Gupta, 2006). High fluoride levels are often associated with regions having fluoride-rich minerals in the geological formations.Nitrite and nitrate are indicators of agricultural runoff and sewage contamination. High nitrate levels in drinking water can cause methemoglobinemia or "blue baby syndrome" in infants (WHO, 2017). Studies have shown that nitrate levels in certain parts of Delhi NCR often exceed the safe limit of 50 mg/L, highlighting the need for effective management of agricultural practices (Suthar et al., 2009). Nitrite and nitrate contamination is commonly linked to the excessive use of nitrogen-based fertilizers and improper waste disposal.Alkalinity, primarily due to the presence of bicarbonates, carbonates, and hydroxides, is a measure of the water's capacity to neutralize acids. It is an important parameter for both drinking and irrigation purposes (APHA, 2012). Groundwater in Delhi NCR generally shows moderate to high alkalinity, reflecting the geological characteristics of the region (Kumar & Singh, 2010). High alkalinity can buffer pH changes, but excessive levels can impact the taste and cause scaling in water distribution systems. Water hardness is caused by the presence of calcium and magnesium ions. While not harmful to health, high hardness levels can lead to scaling in pipes and affect the palatability of water (WHO, 2017). Groundwater in Delhi NCR often exhibits hardness levels above the desirable limit of 200 mg/L, necessitating treatment for domestic use (Sharma & Kansal, 2011). Hard water can also reduce the effectiveness of soaps and detergents, leading to increased consumption.

1.4.2. AGRICULTURAL IMPACT

Groundwater quality also impacts agricultural productivity. High TDS and EC values can affect soil structure and crop yield (Singh & Kumar, 2016). Research indicates that farmers in Delhi NCR are increasingly facing challenges related to soil salinity and reduced crop productivity due to poor water quality (Gupta et al., 2015). Saline water can lead to the accumulation of salts in the soil, reducing its fertility and adversely affecting plant growth. Sustainable irrigation practices and the use of salt-tolerant crop varieties are essential for mitigating these impacts.

Policy and Management Strategies

The regulatory framework for groundwater quality management in India includes guidelines from the Central Ground Water Board (CGWB) and standards set by BIS and WHO. However, enforcement remains a challenge due to fragmented responsibilities and lack of coordination among agencies (CGWB, 2017). Adopting sustainable water management practices is crucial. This includes rainwater harvesting, promoting the use of treated wastewater for irrigation, and implementing strict regulations on industrial discharges (Kumar et al., 2018). Community involvement and awareness campaigns are also essential for successful implementation. Technological interventions such as the use of GIS and remote sensing for monitoring groundwater quality, along with advanced water treatment techniques, can significantly improve water management (Raju et al., 2017). Research highlights the potential of using low-cost sensors and mobile technology for real-time water quality monitoring (Sharma & Kansal, 2011).

1.4.3. HEALTH IMPACTS

Since, the earliest times, groundwater has been extracted for livestock, household use and irrigational purposes. Ever, since the utilization of groundwater has grown consistently. The numbers of successful methods to bring the groundwater to the ground surface have been discovered. Nearly about two third of assets of the freshwater of the planet is constitutes by groundwater. Therefore, groundwater accounts approximately the entire utilizable freshwater if the glaciers and polar ice caps are not taken into consideration. However, if this concern is further restricted to merely the accessible active bodies of groundwater (estimated by Lvovitch, 1972) then they comprise 95 % of entire freshwater. Reservoir, rivers swamps and lakes account for 3.5 % of water and only 1.5 % is accounted by soil moisture (Freeze and Cherry, 1979). Protection of groundwater is essential for human life and financially viable activity of economics. Therefore, it is customary to believe that groundwater is more significant in humid areas than in semi-arid or arid areas. Moreover, the inventories of surface and groundwater usage expose the significance of groundwater to worldwide. This is however due its convenient availability, excellent natural quality and the comparatively less cost of extraction, Thus, the inclusive image of the spatial allocation of groundwater class in terms of quality and the changes with instance that either caused by manmade activities or naturally (Wilkinson and Edworthy, 1981) are vital. As the natural processes of flushing out the contaminants are time-consuming, a groundwater resource once get polluted could remain contaminated for number of decades or sometimes even for thousands of years. Additionally, there is a significant extent of chemical as well as physicochemical processes interdependence among the groundwater and aquifer material. Thus, there is substantial possibility for the alteration of quality of water by interface among the physicochemical processes and aquifer material. The long residence times depending on size and type of the groundwater aquifer enhance the scope of such alterations. Groundwater occurs in number of geological formations of diverse nature. In the upper part of Crust of Earth‘s nearly all rocks inspite of their age, origin or type have openings termed as pores. The minute quantity of gases, dissolved organic matter and extensive range of dissolved solids are present in water beneath the earth surface. As the water always remains in the state of motion and in the subsurface environment intermingle with the aquifer material. Therefore, during the movement of groundwater, enormous concentration of minerals matter may dissolve, move and deposit. Surfaces as well as subsurface environment are primary factors in determining the magnitude of these changes. The rain water composition, compositional characteristics of penetrating surface water, rock and soil properties through which groundwater passes influence the groundwater quality. Moreover, the contact time between groundwater and geological materials that comes across in its pathway, degree of geochemical (ion exchange, dissolution, oxidation, evaporation, reduction) processes and microbiological processes controlled the ionic composition of groundwater. Usually, to a greatest degree the host rock that comprises the aquifers affects the quality of groundwater. Thus, the groundwater resources have an immense potentiality to spread the variety of diseases if they get infected.

This chapter will give an overview of physiochemical and trace elements in groundwater of study area and also how groundwater quality may ground health risk to people of area under study. Quality of the groundwater was determined by the concentration of various chemical constituents derived from the geological data of the specific region. The geological interactions affect the human health by influencing the quality of water. These interactions are even more important particularly in distorted systems for narrow and local population employing this impure water for drinking. In such systems, the water may hold amplified levels of particular elements which are highly detrimental to individual strength of health. Therefore, in the area of multifaceted geology and hydrothermal system is behind the formation of large number of rocks and such type of interactions ought to be assessed effectively. The metals are hold in hydrothermal fluids, imminent either by virtue of leaching of subsurface rocks or nearby igneous source (Henley et. al., 1984). Such type of fluids then causes the alteration of other rocks by changing their chemical composition and mineralogy (Nicholson, 1993; Verma et. al., 2005; Pandarinath et. al., 2008).

The complex zoned alteration patterns have been well known from large number of hydrothermal ore deposit such as epithermal Au–Ag deposits (Arribas, 1995; Hedenquist and Arribas, 1999), porphyry copper deposit (Lowell and Guilbert, 1970; Hedenquist and Richards, 1998) and submarine-volcanogenic massive sulphide (Finlow-Bates and Stumpfl, 1981; MacLean and Kranidiotis, 1987). The concentrations of dissolved contaminants typically rise through water- rock exchanges. The minerals go through the transformations that outline the accessibility and mobility of different elements. Tosham area host sulphide minerals at large extent. Highly acidic conditions can be generated by weathering (oxidative) of pyrite, which increase the rate of solubility of metals commencing gangue silicate, carbonate minerals and other sulfide minerals as well. The tempo of chemical weathering of volcanic rocks is five to ten times higher as compared to that of granite and gneiss (Dessert et. al., 2009). Three types of rock alteration argillic, propylitic, and silicified are observed in numerous region of the earth. In propylitic alteration, partial or totally transformation of phenocryst of mafic minerals e.g. hornblendes and pyroxenes and new minerals are formed as a result of replacement, such as chlorite ± epidot ±carbonate. The foremost exploration targets for shallow high-sulphidation and deeper porphyry type deposits are the regions of argillic alerations (Lerouge et. al., 2004). The alteration of host volcano-sedimentary and volcanic rocks by virtue of acidic and sulphate containing hydrothermal fluids results into formation of alunite (Hemley et. al., 1969). The process dealing with the formation of vuggy silica comprises of pyrite, rutile and quartz is associated with argillic alteration. During the argillic alteration, the Mg, Fe and Ca leach whereas intense Na leakage is obvious in all types of alteration. The enrichment or leaching of various elements is governed by different environmental conditions (Karakaya et. al., 2007). The water quality standards as given in BIS standards (IS-10500, 2012) and probable health effect of consuming drinking water having quality parameters beyond permissible limits are summarized in Table 1.

Table 1 Drinking water standard-BIS (IS-10500, 2012) for drinking purpose and their probable effects

S. No.	**Parameters**	**Prescribed Limits IS:10500, 2012 (mg/L)**		**Probable effects**
		Desirable Limits (mg/L)	**Permissible Limits (mg/L)**	
1	Taste	Agreeable	Agreeable	Makes water aesthetically undesirable
2	Color (Hazen Units)	5	15	Makes water aesthetically undesirable
3	Odour	Agreeable (Essentially free from objectionable odour)	Agreeable	Makes water aesthetically undesirable
4	pH	6.5	8.5	Indicative of basic or acidic nature, affects the flavour, corrosivity and supply system of water.
5	Total Hardness (mg/L as $CaCO_3$)	200	600	The supply system of water gets affected, excess consumption of soap, calcification of arteries, may also ground urinary concretions, stomach disorder and

				bladder or kidney diseases.
6	Chloride (mg/L)	250	1000	Flavour, corrosion, indigestion and palatability are affected and may be damaging to people who have been suffering from disease of heart or kidney.
7	Total Dissolved Solids (mg/L)	500	2000	May reason for gastro-intestinal irritation in human beings and also have laxative effect specifically on transport and corrosion.
8	Calcium (mg/L)	75	200	
9	Magnesium (mg/L)	30	100	
12	Sulphate (mg/L)	200	400	
13	Nitrate (mg/L)	45	No relaxation	
14	Total Alkalinity as Calcium Carbonate (mg/L)	200	600	

In the further chapters, the results of physicochemical analysis of groundwater samples of area under study are given. The composition of groundwater is a collective result of the composition of water that infiltrated beneath the surface of earth and kinetically controlled the reactions with the substance surrounding the aquifer (Appelo & Postma, 2005). Therefore, the principal objectives of this study are (a) to analyse the hydrogeochemical characteristics and facies of groundwater; (b) to assess the overall groundwater quality using Water Quality Index (WQI) method; (c) to evaluate the groundwater quality for drinking and irrigation purposes using multiple water quality indicators such as sodium adsorption ratio (SAR), sodium percentage

(%Na+), residual sodium carbonate (RSC), magnesium hazard ratio (MHR), and Kelly ratio (KR).

MATERIALS & METHODOLOGY

2. LR

2.1.STUDY AREA

The study focuses on Faridabad, a prominent industrial city in the northern Indian state of Haryana. Situated in the National Capital Region (NCR) bordering Delhi, Faridabad is one of the major satellite cities with a significant population and rapid urbanization. The city lies between latitudes 28.25°N and 28.45°N and longitudes 77.15°E and 77.45°E, encompassing an area of approximately 741 square kilometres. Faridabad is divided into multiple sectors and industrial areas, including DLF Industrial Area, Gurukul Industrial Area, and various residential sectors such as Sector 24, Sector 25, and Sector 27.

2.2.GEOGRAPHICAL AND CLIMATIC FEATURES

Faridabad features a semi-arid climate characterized by hot summers, a brief monsoon season, and mild winters. The average annual rainfall is around 500 mm, primarily received during the monsoon months of July and August. The Yamuna River flows to the east of the city, providing a crucial water source for both industrial and agricultural activities. The region's topography is predominantly flat with some areas of minor undulations.

2.3.ECONOMIC AND AGRICULTURAL SIGNIFICANCE

Faridabad is a vital industrial hub with diverse manufacturing sectors, including machinery, automotive, electronics, and textiles. The agricultural areas around the city primarily cultivate crops such as wheat, rice, and sugarcane, relying heavily on irrigation due to the semi-arid climate. Water quality for irrigation is thus a critical factor affecting agricultural productivity and sustainability in the region.

2.4.STUDY LOCATIONS

The water quality study encompasses various key locations in Faridabad, including:

- DLF Industrial Area Phase 1
- Sector 24
- Mathura Road

- Sector 27A
- Village Etmadpur
- Mouja Sidola
- Gurukul Industrial Area
- Sector 27C
- Village Dabua, NIT Faridabad
- Sareen Complex
- Sector 25
- Village Softa

These locations represent a mix of industrial, residential, and agricultural zones, providing a comprehensive overview of the water quality across different land use types within the city.

2.5.ANALYSIS OF WATER

(i) pH

The concentration of hydrogen ions in water is measured by pH. It is equivalent to minus log 10 of the concentration of hydrogen ions and is measured on a log scale. A hydrogen ion-sensitive electrode or a colorimetric approach using a variety of markers can be used to determine pH. On the spot, a Labmann LMMP 30 Model Multimeter kit was used to measure pH.

(ii) TOTAL DISSOLVED SOLIDS (TDS)

Many types of minerals in the water are indicated by TDS. There are no colloids or gas in TDS. These can be identified as the residue that remains after the filtered sample evaporates. Additionally, the Labmann LMMP 30 Model Multimeter kit was used to measure this.

(iii) CONDUCTIVITY

Conductivity refers to the ability of a substance or solution to carry an electric current. Conductivity is a quantitative assessment of the presence of positively charged cations and negatively charged anions in a given sample. The measurement was also conducted using the Labmann LMMP 30 Model Multimeter kit.

(iv) **SALINITY**

Salinity is the quantitative assessment of the total amount of salts that are dissolved in water. Typically, it is quantified in units of parts per thousand. Salinity has a crucial role in influencing various aspects of the chemical composition of natural water and the biological processes occurring within it. It is a thermodynamic state variable that, together with temperature and pressure, regulates physical properties such as water density and heat capacity. The measurement was also conducted using the Labmann LMMP 30 Model Multimeter kit.

(v) **ALKALINITY**

Water's alkalinity refers to its ability to counteract acidity. The quantity of a potent acid required to counterbalance the alkalinity is referred to as the total alkalinity, denoted as T, and is expressed in milligrams per liter as calcium carbonate (CaCO3). The alkalinity of certain waters is solely attributed to the presence of calcium and magnesium bicarbonates. The water's pH does not surpass 8.3, and its total alkalinity is essentially the same as its bicarbonate alkalinity. The stoichiometric connections between hydroxide, carbonate, and bicarbonate are accurate only when there are no significant concentrations of other weak anions present. This particularly pertains to the alkalinity (and acidity) of contaminated bodies of water and wastewater.

Procedure

Mix 50 ml of the sample with a little amount of phenolphthalein indicator, consisting of two or three drops, in either a porcelain basin or a conical flask placed on a white surface. If there is no coloration, it indicates that the alkalinity of phenolphthalein is zero. To determine the alkalinity, titrate the sample with standard acid till the pink or crimson coloration disappears. Regardless of the situation, proceed with the analysis using the sample that has been supplemented with phenolphthalein. Introduce a little amount of methyl orange indicator by dripping a few drops. If the sample appears orange in the absence of acid, then the total alkalinity is determined to be zero. Titrate the sample with standard acid until the first noticeable shift in color from yellow to orange is detected.

Calculations:

Phenolphthalein alkalinity as CaCO3

$$P = \frac{V1 * N1 * 50 * 1000}{V}$$

Total alkalinity (T) as CaCO3 (mg/l)

$$T = \frac{V2 * N1 * 50 * 1000}{V}$$

V1 = Volume of standard acid solution (mL) to reach the phenolphthalein endpoint of pH 8.3

V2 = Volume of standard acid solution (mL) to reach the endpoint of methyl orange

N = Normality of acid used

V = Total volume of sample (mL)

Using 100 ml of sample and 0.01 mol L-1 standard acid solutions, the numerical value of alkalinity as mg L-1 CaCO3 is 10 times the number of millilitres of titrant consumed.

(vi) TOTAL HARDNESS

In the beginning, water hardness was defined as the ability of water to cause soap to form a precipitate. The precipitation of soap is mostly caused by the presence of calcium and magnesium ions. Additional polyvalent cations can also cause soap precipitation, although they are generally present in complex forms, often with organic components, and their contribution to water hardness may be insignificant and hard to determine. According to the prevailing convention, total hardness is determined by adding together the amounts of calcium and magnesium, which are both measured in milligrams per liter and expressed as calcium carbonate.

When the numerical value of hardness exceeds the combined value of carbonate and bicarbonate alkalinity, the portion of hardness that is equal to the total alkalinity is referred to as "carbonate hardness," while the remaining portion of hardness is referred to as "non-carbonate hardness." When the numerical value of hardness is equal to or less than the combined value of carbonate and bicarbonate alkalinity, all of the hardness is classified as carbonate hardness and there is no presence of non-carbonate hardness. The hardness of water can vary from zero to several hundred milligrams per liter, depending on the source and the treatment it has undergone.

Procedure

1. Take 50 ml of the sample in a conical flask.
2. Add 1 ml buffer solution, then add a pinch of Erichrome Black T.

3. Titrate with standard EDTA titrant till the colour changes to distinct blue.

Calculations

$$Hardness\ (EDTA)\ as\ CaCO3\ \left(\frac{mg}{L}\right) = A * B * 1000\ (mL\ sample)$$

Where,

A = mL titration for sample and

B = mg CaCO3 equivalent to 1.00 ml EDTA titrant (=1)

3.6.CATIONS

3.6.1. FLAME PHOTOMETRY

Flame photometry, also known as flame atomic emission spectrometry, is a specific field within atomic spectroscopy that focuses on analysing atoms in the spectrometer. Atomic absorption spectrophotometry and inductively coupled plasma-atomic emission spectrometry (ICP-AES) are the other two branches of atomic spectroscopy. ICP-AES, albeit a relatively new and costly method, is not utilized in Standard base investigations. Regardless of the scenario, the atoms being studied are stimulated by light. Absorption techniques quantify the absorbance of light resulting from the transition of electrons to a higher energy state. Emission techniques quantify the luminosity emitted when electrons transition to lower energy levels. Flame photometry is an appropriate method for both qualitative and quantitative analysis of various cations, particularly for metals that can be easily stimulated to greater energy levels at a relatively low temperature of the flame. These metals include sodium (Na), potassium (K), rubidium (Rb), caesium (Cs), calcium (Ca), barium (Ba), and copper (Cu). This method employs a flame to vaporize the solvent, as well as to sublimate and atomize the metal. Subsequently, it stimulates a valence electron to transition to a higher energy level. Each metal emits light at specific wavelengths when its electrons return to the ground state, allowing for qualitative evaluation. Flame photometers employ optical filters to detect the specific emission wavelength generated by the analyte species. By comparing the emission intensities of unknowns to either the emission intensities of standard solutions (using a calibration curve) or to those of an internal standard (using the standard addition method), it is possible to do quantitative analysis of the metal being analyzed in the sample solution. Flame photometry relies on measuring the luminosity of light released when a metal is placed into a flame. A photoelectric flame photometer is an instrument utilized in the field of inorganic chemical analysis for the purpose of quantifying the concentration of specific metal ions, including sodium, potassium, lithium, and calcium. The wavelengths of the color provide information on the identity of the element, while the color intensity indicates the quantity of the element present. Flame photometry is alternatively referred to as flame emission spectroscopy due to its utilization of a flame to supply the necessary energy for exciting atoms placed into the flame. Essentially, it is a method of testing flames where the intensity of the flame's color is measured using photoelectric electronics. The sample is exposed to the flame at a consistent rate. Filters are used to specifically choose the color that the photometer detects, while simultaneously eliminating the impact of other ions. Prior to usage, the instrument necessitates calibration by utilizing a sequence of reference solutions containing the specific ion to be examined. The spectrophotometer technique is widely recognized as a very reliable and often employed method for quantifying the levels of Sodium, Potassium, Calcium, and Magnesium.

Procedure

Operating Instructions:

1. Open the lid of the filter chamber. Insert an appropriate filter for the test opening and close the lids.
2. Insert the free end of the PVC takes up capillary in distilled water or the reagent. Adjust set zero controls to obtain 00 display on the readout.
3. Adjust the control of each channel to obtain a display exactly 100 on the readout of the channel.
4. Repeat operation of steps 3 and 6 to ensure 00 and 100 are displayed respectively when the blank and the working standard solution of highest concentration are aspirated into the flame.
5. Insert the free end of the PVC takes up capillary in distilled water for a minute or two to wash the mixing chamber thoroughly before the actual test.
6. Insert the free end of the PVC takes up capillary in the sample read the value of the concentration as displayed in the readout.

7. Feed the working standard solution of known concentration from time to time in a series of test to check the calibration. Check the 00 with the blank solutions. Beakers, Glass rod.

Calculations

$$Concentration\ of\ Na+, K+, Ca2+\left(\frac{mg}{L}\right) = \left(\frac{mg}{L}\ samples\ in\ diluted\ liquid\right) * Dilution\ Factor$$

a. **SODIUM**

It is a significant naturally occurring cation. Domestic sewage is a significant contributor of sodium to freshwater ecosystems. Sodium salts exhibit excellent solubility in water. Water with a high salt level is unsuitable for agriculture due to its tendency to degrade the soil for crops. The presence of sodium in the form of chlorides and sulphides renders the water unpleasant. The sodium concentration is determined using the flame photometry technique.

b. **POTASSIUM**

Potassium is an element that occurs naturally. Nevertheless, the concentration remains significantly lower compared to sodium, calcium, and magnesium. Sodium has a significant degree of chemical affinity and tends to remain predominantly dissolved without undergoing precipitation. The content of potassium is determined using the flame photometry method, which is also employed for measuring sodium levels.

c. **CALCIUM**

Calcium is a vital element derived from crystalline sources. It is a fundamental constituent of the majority of rock minerals and ores. The pace at which a mineral rock dissolves in water is determined by its weathering profile. The excessive breakdown of calcium salt leads to an elevation in the overall hardness of water. Calcium ions at the water/soil interface control the Cation Exchange Capacity (CEC) of soil and the absorption of nutrients from the soil. It also impacts the concentration of cations in water, which in turn influences the quality of irrigation water. At elevated pH levels, a significant portion of its amounts may undergo precipitation as calcium carbonate ($CaCO3$).

Procedure

Take the volume of sample in a conical flask

To maintain the pH add 1 ml of a strong base i.e. 1N NaOH.

Add a pinch of murexide indicator. the solution turns pink in colour

Titrate the solution against 0.01M EDTA. The end pint is pink to blue.

Calculation

$$Ca\left(\frac{mg}{L}\right) = \frac{Vol. of\ EDTA\ used * Molarity\ of\ EDTA * 40 * 1000}{Vol. of\ sample}$$

d. MAGNESIUM

It is present in several types of natural water, but its amount is often lower than that of calcium. Similar to calcium, it is also one of the crucial ions that contribute to water hardness. The concentration of magnesium is calculated by subtracting the titration value for calcium alone from the combined titration value of calcium and magnesium.

Calculation

$$Mg\left(\frac{mg}{L}\right) = \frac{((y - x) * 400.8) * 1.645}{mL\ of\ sample}$$

Where, x = EDTA used for Ca determination

y = EDTA used for hardness (Ca + Mg)

3.7.ANIONS

a. CHLORIDE

Chlorides are present in all-natural bodies of water at highly diverse quantities. If the concentration is below 250 mg/litre, they pose no danger to people.

The Argentometric technique is commonly used to measure chlorides. This approach suggests utilizing a 0.0141N solution of silver nitrate for the process of titration.The molar concentration of chloride ions in this silver nitrate solution is 0.5 mg/mL. During the process of titration, the chloride ion is transformed into a solid form known as silver chloride, which appears white in color.

$Ag^+ + Cl^- \leftrightarrow AgCl$

The eye is unable to detect the endpoint. An indication is utilized to identify the presence of an excessive amount of Ag+. The commonly employed indicator is potassium chromate, which provides the chromate ions. When the concentration of Chloride ions becomes extremely low, the concentration of silver ions rises to a point where it exceeds the solubility product of silver chromate. As a result, a reddish-brown precipitate starts to form.

$2Ag^{+} + CrO_4^{2-} \leftrightarrow Ag_2CrO_4$

This is taken as evidence that all the chloride has been precipitated.

Procedure

1. Take a 100 ml sample in a beaker.
2. Adjust sample pH to 7 to 10 with H2SO4 or NaOH if it is not in this range.
3. Add 1 ml potassium chromate indicator solution.
4. Titrate with standard AgNO3 titrant to a pinkish-yellow endpoint.
5. Standardise the AgNO3 titrant and establish a reagent blank value by the above titration method.

Calculation

$$Cl - \left(\frac{mg}{L}\right) = \frac{(A - B) * N * 35450}{mL\ of\ sample}$$

Where,

A = mL of titration for the sample

B = mL of titration for blank

N = Normality of $AgNO_3$

b. SULPHATE

Sulphate is ubiquitously found in nature and can be found in natural bodies of water at concentrations ranging from a few hundred to several thousand milligrams per liter. The turbidity metric method for measuring sulphates relies on the observation that barium sulfate has a tendency to precipitate in a colloidal form of consistent size. This tendency is further exacerbated in the presence of sodium chloride, hydrochloric acid, and glycerol.

$SO_4^{2-} + BaCl_2 \rightarrow BaSO_4$

The spectrophotometer measures the absorbance of the barium sulphate generated at a wavelength of 420 nm. The concentration of sulfate ions is then estimated by comparing the reading with a reference curve.

Procedure

1. Transfer blank to the sample tubes and place it in the chamber. Now the value of absorbance for the blank is displayed as 0.0185.
2. Then take standard 1 in the sample tube and place it in the chamber and take the reading.
3. Similarly, take readings for the rest of the samples

Calculation

$$Concentration\ of\ Sulphate\ \left(\frac{mg}{L}\right) = \frac{X * 1000}{Vol.of\ sample\ (mL)}$$

Where, X = Sulphate (mg)

c. FLUORIDE

Procedure

i. Stock Solution Preparation (1000 mg/l F^-)

Weigh 0.221 g of NaF, which was priorly dried for 120 mins at 110°C and stored in a desiccator. Dissolve the weighed NaF using distilled water and dilution was carried up to the 100 ml mark.

ii. Standard Solution Preparation (100 mg/l F-)

Using a pipette, 10 ml of the stock solution was diluted using 100 ml of distilled water in a volumetric flask. Similarly, two more standard solutions i.e. 1.0 mg/l F- and 0.1 mg/l F- was prepared.

iii. Calibration of Ion-Selective Electrode (ISE)

Fluoride ISE is calibrated using standards that cover the expected sample concentration range.

1. Rinse electrodes and immerse in a standard of known concentration. Allow values to stabilise.

2. Once steady, the value is stored and step 1 is repeated for the other two standards.

3. A 3-point calibration curve is prepared by plotting the measured potential (mV) against the Fluoride concentration (mg/l).

4. If the slope is in the acceptable range (54-60 mV per decade of F), correction is not required. Calibration is completed.

iv. Fluoride concentration determination

1. Rinse the electrode thoroughly with distilled water and wiped using tissue paper to get rid of the excess of water.

2. The electrode is immersed in the sample and allow to steady. Value is noted.

3. Step 1 and 2 are repeated for determining the concentration of F in other samples.

3.8.SUITABILITY FOR IRRIGATION

The advancement in the management of effective irrigation projects include not only the provision of water to the land but also the regulation of the levels of alkali and salt that reach the soil. The key attributes of irrigation water that are crucial for assessing its quality include:

1. Percent Sodium (% Na)

2. Soluble Sodium Percent (SSP)

3. Sodium Absorption Ratio (SAR)

4. Magnesium Hazard

5. Kelly's Ratio

3.8.1. PERCENTAGE SODIUM (%Na)

The sodium proportion is a crucial component to consider while studying the salt hazard. The calculation involves determining the percentage of sodium and potassium in relation to the total concentration of cations. Additionally, it is employed for assessing the water quality for agricultural purposes. The utilization of water with a high concentration of salt inhibits the growth of plants. Sodium chemically interacts with the soil, resulting in a decrease in its permeability. The sodium concentration in water is the measure calculated to assess its appropriateness for irrigation. Typically, only minimal issues arise when the concentration of sodium (%Na) is below 15%. Nevertheless, if the percentage surpasses 15, it leads to decreased permeability. The impact of salt on water infiltration and aeration will be larger when the soil texture is finer and the organic matter content is higher. Gypsum can be used as a soil amendment to mitigate the impact of elevated sodium levels in irrigation water.

$\%Na = [(Na^+ + K^+) * 100] / (Ca^{2+} + Mg^{2+} + K^+)$

3.8.2. SOLUBLE SODIUM PERCENT (SSP)

If the percentage is below 60 percent, as stated by Eaton (1950), the water sample is considered to be of good quality and appropriate for irrigation. Conversely, a proportion exceeding 60 is considered to be of low quality and not suited for irrigation.

$SSP = [Na^+ / (Ca^{2+} + Mg^{2+} + Na^+)] * 100$

3.8.3. SODIUM ABSORPTION RATION (SAR)

The Surface Absorption Rate (SAR) is a highly valuable indicator for assessing the appropriateness of surface water for irrigation, as it quantifies the level of alkalinity and sodium hazard. The sodium adsorption ratio (SAR) quantifies the ratio of sodium (Na) to calcium (Ca) and magnesium (Mg) in the water extract obtained from a saturated soil paste. The ratio is calculated by dividing the concentration of Na by the square root of half the sum of the concentrations of Ca and Mg. Soils with SAR values of 13 or above exhibit enhanced dispersion of organic matter and clay particles, decreased saturation hydraulic conductivity (Ksat) and aeration, and overall deterioration of soil structure. Na is regarded as a significant determinant of irrigation water due to its impact on soil and plants. The formula can be used to determine it:

$SAR = Na^+ / [(Ca^{2+} + Mg^{2+})/2]^{0.5}$

3.8.4. MAGNESIUM HAZARD

An abundance of magnesium in the soil has a negative impact on the productivity of crops. A magnesium ratio beyond 50 is deemed detrimental and inappropriate. The presence of surface water and sub-surface water flowing through limestone, granite rock formations, and other geological features in the studied area may explain this phenomenon. The hazard is determined by the following calculation:

Mg Hazard = $(Mg^{2+} * 100) / (Ca^{2+} + Mg^{2+})$

3.8.5. KELLY'S RATIO

Kelly proposed in 1951 that the issue of sodium in irrigation water might be effectively addressed by using Kelly's ratio. Typically, when the KR value is greater than 1, it is deemed unsuitable for irrigation. The calculation is performed in the following manner:

KR = $Na^{+} / (Ca^{2+} + Mg^{2+})$

This study conducted an analysis of water quality in different areas of Faridabad. The study specifically examined important factors including pH, Total Alkalinity, Total Hardness, Total Dissolved Solids (TDS), Chloride (Cl), Nitrate (NO3), Sulfate (SO4), Sodium (Na), Potassium (K), Calcium (Ca), and Magnesium (Mg). The observed results were compared to the guideline values set by the Bureau of Indian Standards and World Health Organization to determine if the water is suitable for consumption.

RESULTS AND DISCUSSION

4.1.GROUNDWATER HYDROCHEMISTRY

The table below presents the result of water quality analysis at present from different sites in Faridabad. The parameters to be determined covered majorly pH, Total Alkalinity, Total Hardness, TDS, Chloride, Nitrate, Sulphate, Sodium, Potassium, Calcium, and Magnesium. Results are compared with the standards of BIS and WHO to check the suitability for drinking apart from other uses.

Table 2 Groundwater quality parameters at selected sites

Locations	**Colour**	**pH**	**TA**	**TH**	**TDS**	**Cl^-**	**NO_3^-**	**SO_4^{2-}**	**Na^+**	**K^+**	**Ca^{2+}**	**Mg^{2+}**
DLF IND AREA PHASE 1 FARIDABAD	Colourless	6.8	550	350	654	324	24	154	82	19	135	215
SEC-24 FARIDABAD	Colourless	7.2	480	450	1750	873	25.17	326	95	29	224	226
MATHURA ROAD, FARIDABAD	Colourless	7.4	520	330	750	355	29	184	78	22	134	196
Sector27A FARIDABAD	Colourless	7	432	425	960	432	28	203	65	19	80	345
VILLAGE ETMADPUR, FARIDABAD	Colourless	7.1	491	320	750	330	19	140	102	15	115	205
MOUJASIDOLA , FARIDABAD	Colourless	8.1	609	755	1173	678	32	320	45	18	160	595
GURUKUL INDUSTRIAL AREA, FARIDABAD	Colourless	6.7	450	350	667	354	25	158	66	22	180	170
SECTOR 27C FARIDABAD	Colourless	7.3	270	365	1365	270	19.6	118	122	36	212	153
DLF INDUSTRIAL AREA PHASE 1 FARIDABAD	Colourless	7.2	670	230	580	132	15	223	48	12	124	106
VILLAGE DABUA, NIT FARIDABAD	Colourless	7.8	580	310	1420	634	17	228	124	34	186	124
SAREEN COMPLEX, FARIDABAD	Colourless	7.1	347	230	2207	132	19	261	112	18	124	106
SECTOR 25 FARIDABAD1	Colourless	7	250	440	6180	124	21	241	772	777	285	155
SECTOR 278 FARIDABAD	Colourless	7.1	380	230	1107	132	19	261	68	21	120	110
VILLAGE SOFTA FARIDABAD Haryana	Colourless	6.8	289	470	3270	2450	23	252	424	394	305	165

SECTOR 25 FARIDABAD21	Colourless	7	247	475	6220	124	21	241	302	17	196	279

4.1.1. pH LEVEL

It elaborates on the pH level in all the water samples taken from different locations within Faridabad. Each bar shows the level of pH measured in each different area. The pH of all the studied locations is under the permissible limit that exists between 6.5 and 8.5 (displayed with the red and green dashed lines). This means the water is just safe to drink, and it is neither acidic nor alkaline, according to the BIS and WHO standards. Each label of location is tilted so that it becomes more readable. The grid lines help to compare different places, which have the pH levels. This means that the uniformity of the property of water would be across all locations.

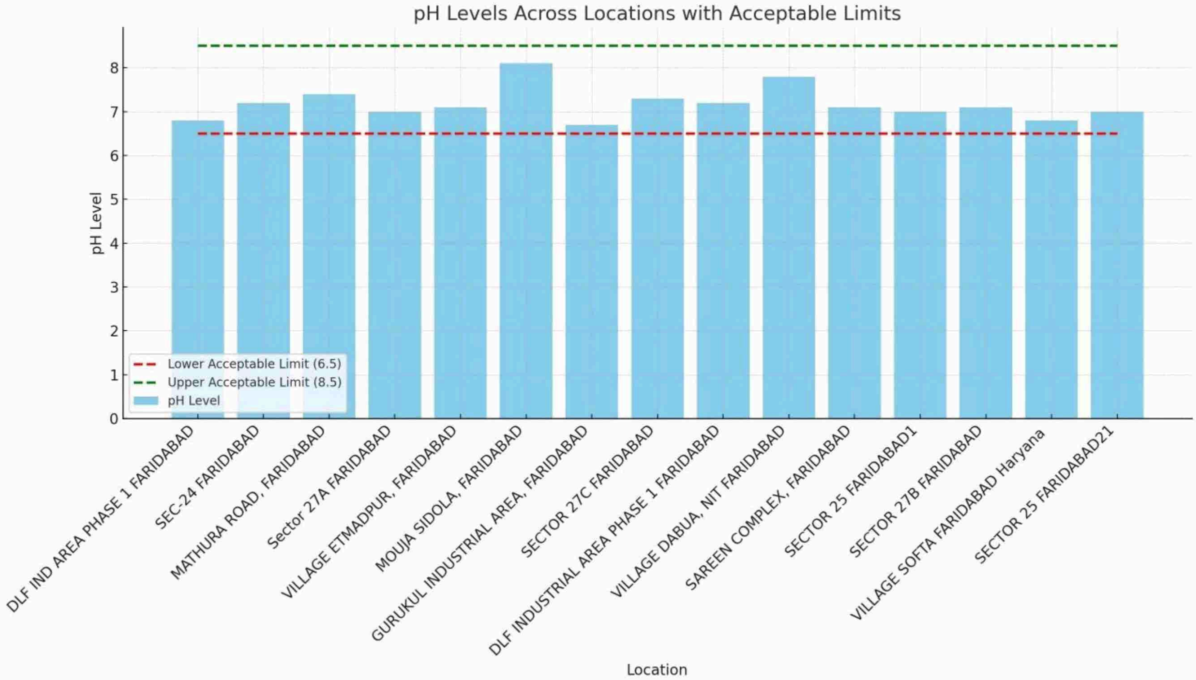


Figure 3 pH Levels across study site

4.1.2. TOTAL ALKALINITY

Bar graph of the Total Alkalinity of different water samples collected from various sites in and around Faridabad. Each bar represents a location, and the height on the y-axis gives the Total

Alkalinity in mg/L. A red dashed line indicates BIS normativity of 200 mg/L; limits on the green dashed line are set at 600 mg/L. Well, to be very precise, our observation from the graph is quite evident in mentioning that all the places are crossing the desirable limit, which raises hydration over and above the desirable value to the extent that would affect water taste and also cause scaling in the pipes. But again, all values are within the permissible limits, which indicates that if alkalinity is high, it is safe for drinking, according to BIS. The following chart demonstrates the interest in technologies for water treatment to reduce alkalinity to levels that are more conducive to better quality water.

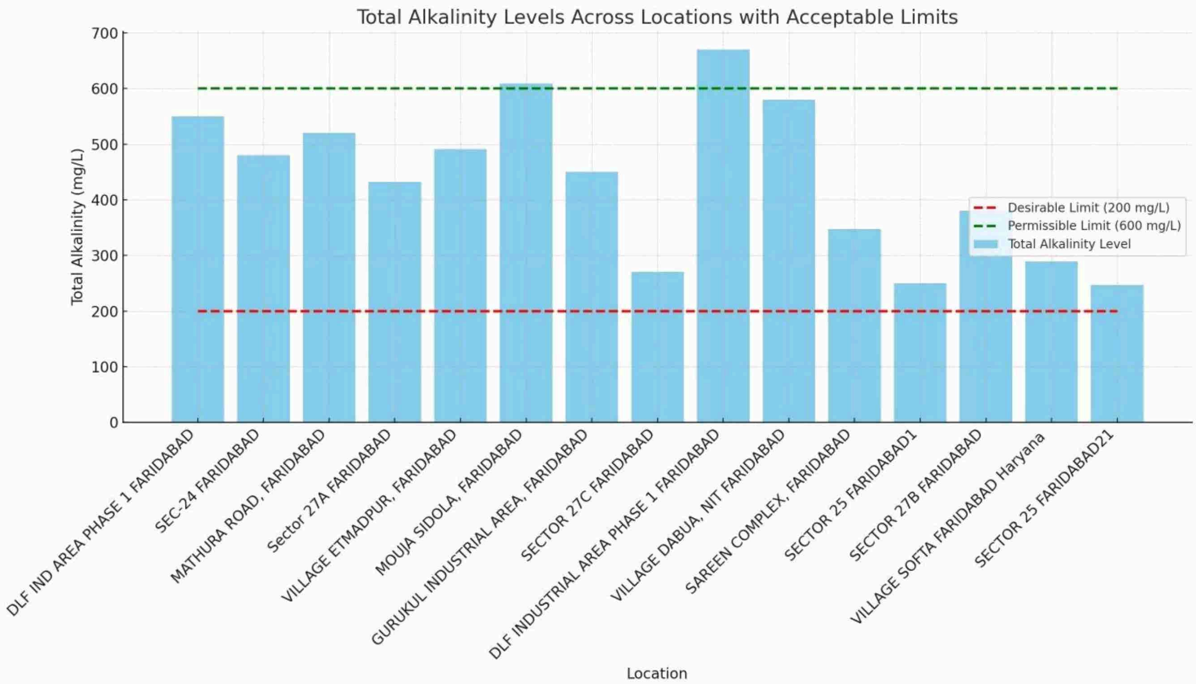


Figure 4 Total Alkalinity (TA) Levels across study site

4.1.3. TOTAL HARDNESS

The bar graph below represents the total hardness of water samples collected from different points located in the city of Faridabad. From this graph, each bar represents a location, and the height of the bars shows the total hardness measured in mg/L. The red dashed line depicts the permissible desirable limit of 200 mg/L as recommended by BIS. The green dashed line indicates the allowable limit of 600 mg/L. As can be visualized from the graph, the Total Hardness levels supersede the desirable limit at all places, which may, therefore, increase the scale in the plumbing systems and the reduced effectiveness of soap. However, it may be noted from the figure that all measurements are significantly within the permissible limit, suggesting that although high, it is at a level acceptable under BIS guidelines. It, therefore, shows the necessity of measures, including water-softening ones, in reducing hardness to preferable levels for use in domestic and industrial activities.

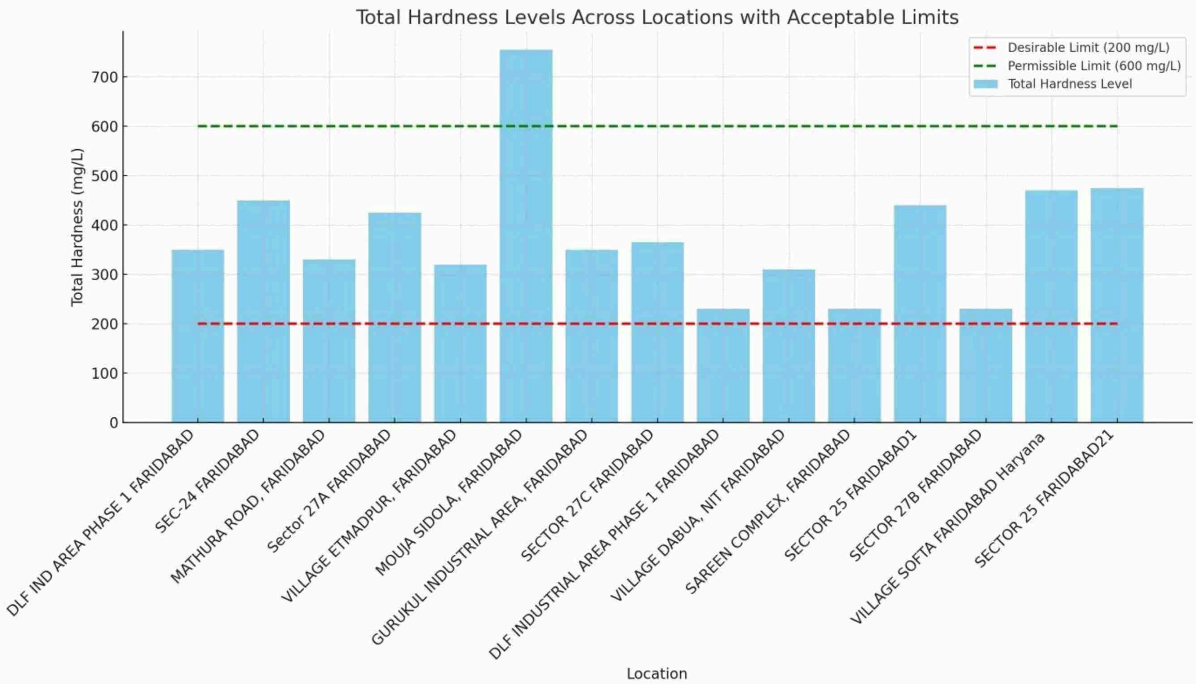


Figure 5 Total Hardness (TH) across study site

4.1.4. TOTAL DISSOLVED SOLIDS (TDS)

Bar graph related to the concentration of Total Dissolved Solid (TDS) in the water samples taken from different locations across Faridabad. Where each bar represents a location and the height of the bar represents the TDS concentration measured in mg/L, the desirable limit as per BIS standards is represented with the red dashed line, 500 mg/L, and the permissible limit is 2000 mg/L represented with the green dashed line. From the graph, it can be seen that the content of TDS in all the locations mentioned above was high and above the desirable limit according to the BIS standards; they were also affecting the taste of water with long-term health effects. The measurements, however, are within permissible limits. On the face of it, high levels of TDS are across tolerable limits for drinking. This visualization shows the need for the treatment of water to bring down TDS and, thereby, raise the quality and safety level of the water.

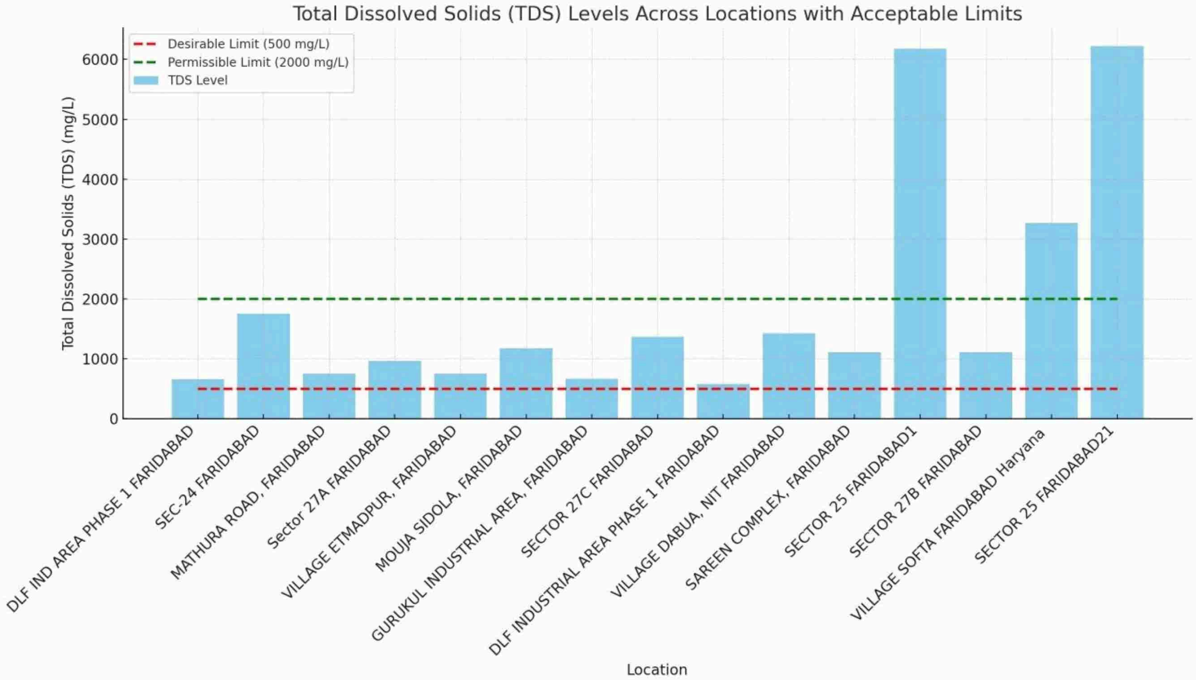


Figure 6 TDS Levels across study site

4.1.5. CHLORIDE (Cl)

Bar graph: Water samples for the contents of Chloride (Cl) from different locations within Faridabad. The height of a bar is the concentration of the chloride measured in mg/L. The Desirable Limit, given as a red dashed line at 250 mg/L, is per the BIS standards. The Permissible Level is offered as a green slashed line at 1000 mg/L. From the graph, it is shown that the values in all locations are above the recommended limits, which will make the water taste salty, and in the least, it may be contributing to the corrosion of the pipes. However, the values for every measurement are within an acceptable limit, which suggests that the values of chlorides, even though high, are still maintainable at an allowable rate for consumption purposes. As such this, therefore, shows a need for water treatment toward the reduction of chlorides in water to make it taste nice and, at the same time, avoid pipe corrosion.

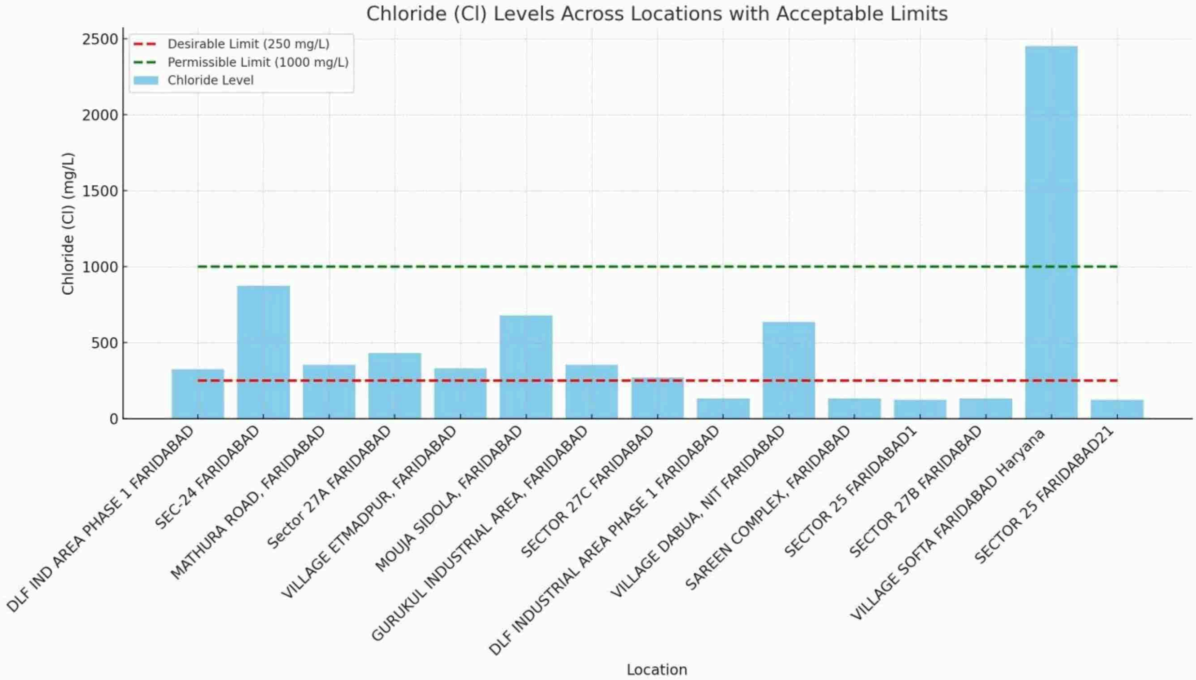


Figure 7 Chloride Levels across study site

4.1.6. NITRATE (NO_3)

The bar representation below is of nitrate (NO3) levels of different locations in Faridabad for water samples. Each bar of this representation is, in essence, denoting some location concerning the concentration of nitrate in the water sample, which is in mg/L. The green dash line marks the permissible level according to the BIS standards, in other words, 45 mg/L. The graph also indicates the fact that there are Nitrate points that have values that are way too high for the allowed limit and concentrations of the Nitrate are suitable for drinking and not considered to be adverse to public health. The graph confirms the fact that nitrates can not be the main issue to be of concern with the water samples that have been tested.

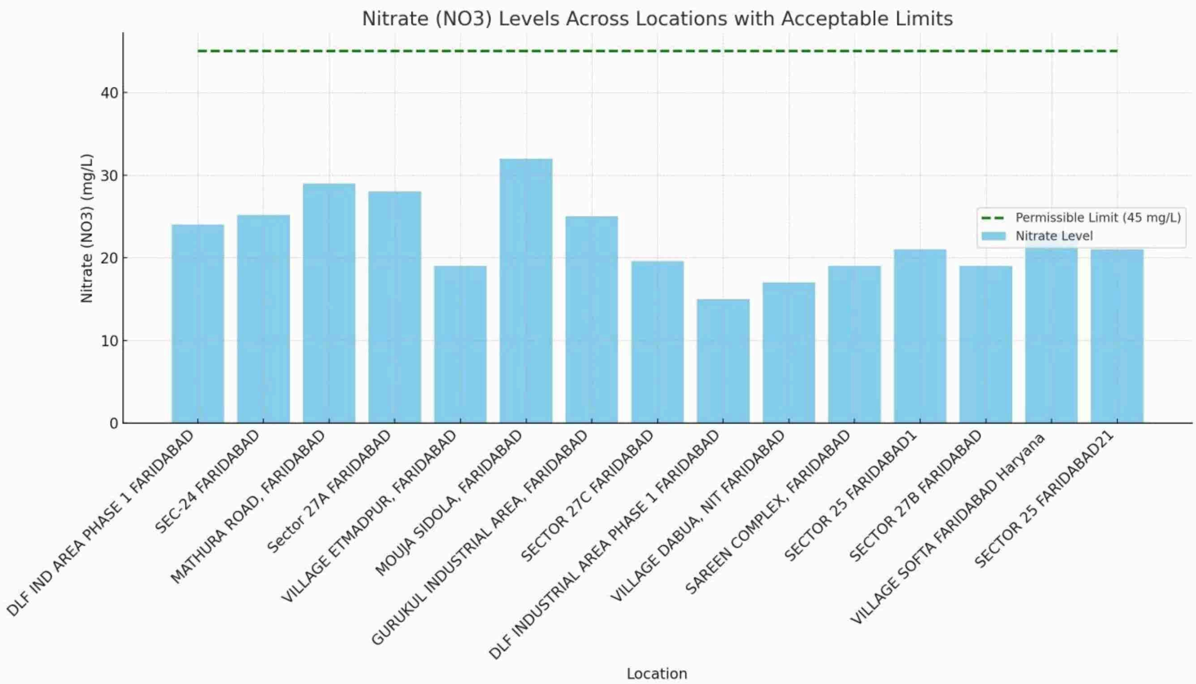


Figure 8 Nitrate Levels across study site

4.1.7. SULPHATE (SO_4)

This bar graph enumerates the bar for the Sulfate (SO4) levels found in samples of water taken from different places in Faridabad. The bar reflects the location, and the height of the bar corresponds to the Sulfate concentration in mg/L. The red dashed lines, on the other hand, are 200 mg/L of BIS desirable limits, and the green dashed line is 400 mg/L of permissible limit. As can be seen from the graph, the graph remains higher than the desirable limit for quite a few locations, but it goes below the desirable limit as well. High Sulfate: > 250 mg/L High levels in the water will cause a bitter taste and maybe a laxative. The following number should point out that it has to be monitored from time to time and, if need be, treated to keep sulfate within the desirable limits for taste and water safety.

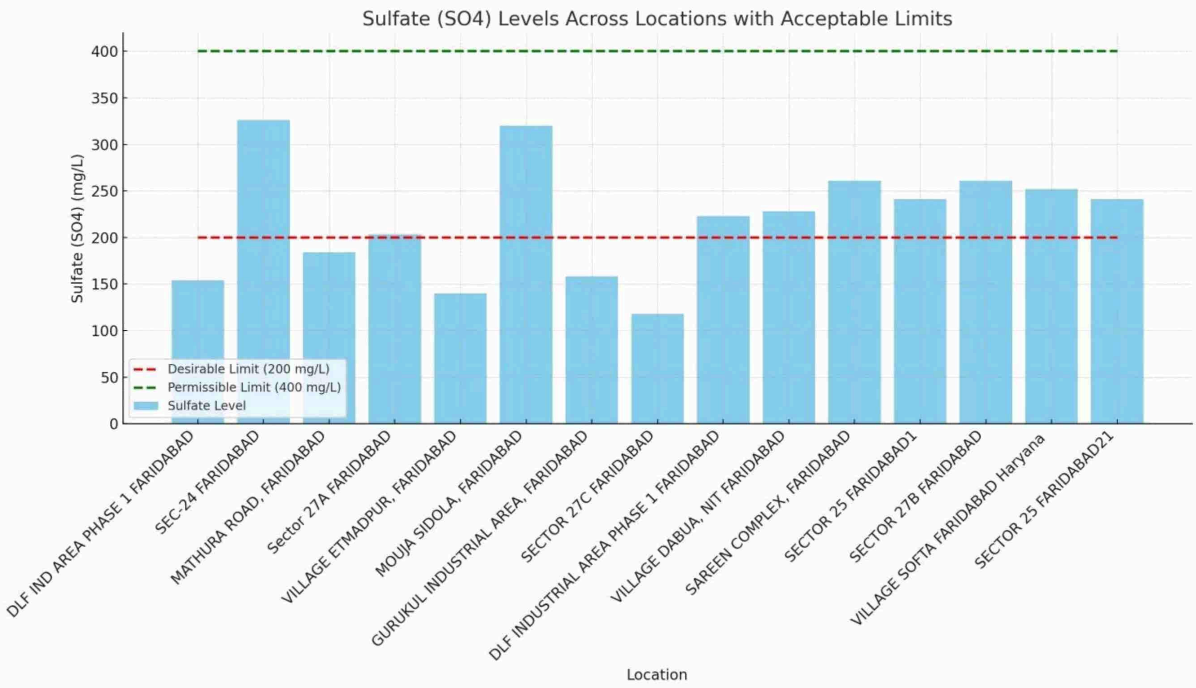


Figure 9 Sulphate Levels across study site

4.1.8. SODIUM (Na)

The graph above shows the concentration of Na (mg/L) in water samples collected from different locations in Faridabad. Every bar indicates the place, and the height of the place on the bar provides an indication of the concentration of Sodium in mg/L measured. The green dashed line is the allowable limit prescribed by WHO: 200 mg/L. According to the chart, concentration levels of Sodium are far below the impactful limit, so with the help of this, we can say that Sodium is being consumed within safe limits. This scatter gives the reason as to why Sodium contamination is not significant in the water samples under study, thus suggest in there are no immediate health consequences linked to Sodium levels in these locations.

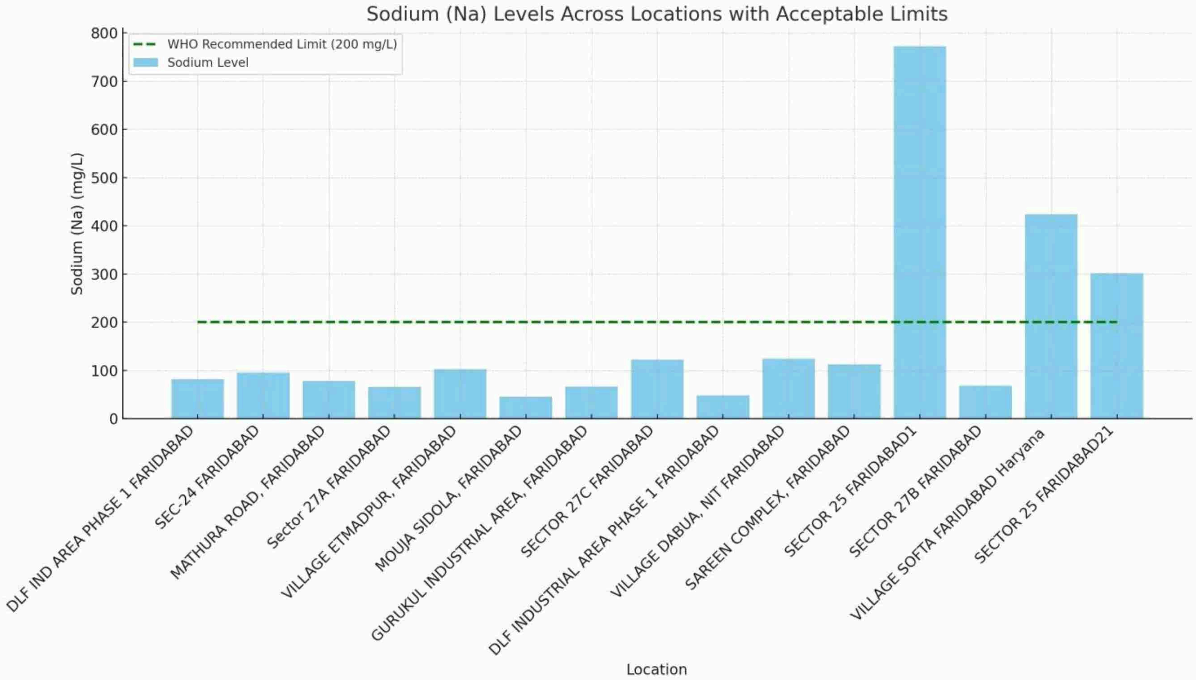


Figure 10 Sodium Levels across study site

4.1.9. POTASSIUM (K)

The bar graph below represents the concentration of Potassium (K) in the water samples collected from different locations in Faridabad. Each bar will represent a location and its height, the potassium concentration noted in mg/L. The red dashed line shows the normal natural range upper limit of 20 mg/L, and by this figure, it is presented that in most of the points, the Potassium is much higher than this natural range. This little higher concentration of Potassium does not show any sort of health concern, but its regular monitoring is necessary to keep the level of Potassium within the normal range of the natural level, which could not let the other general quality of water get deteriorated. The bar graph above represents the concentration of Calcium (Ca) in the water samples collected from the five different sampling stations in Faridabad

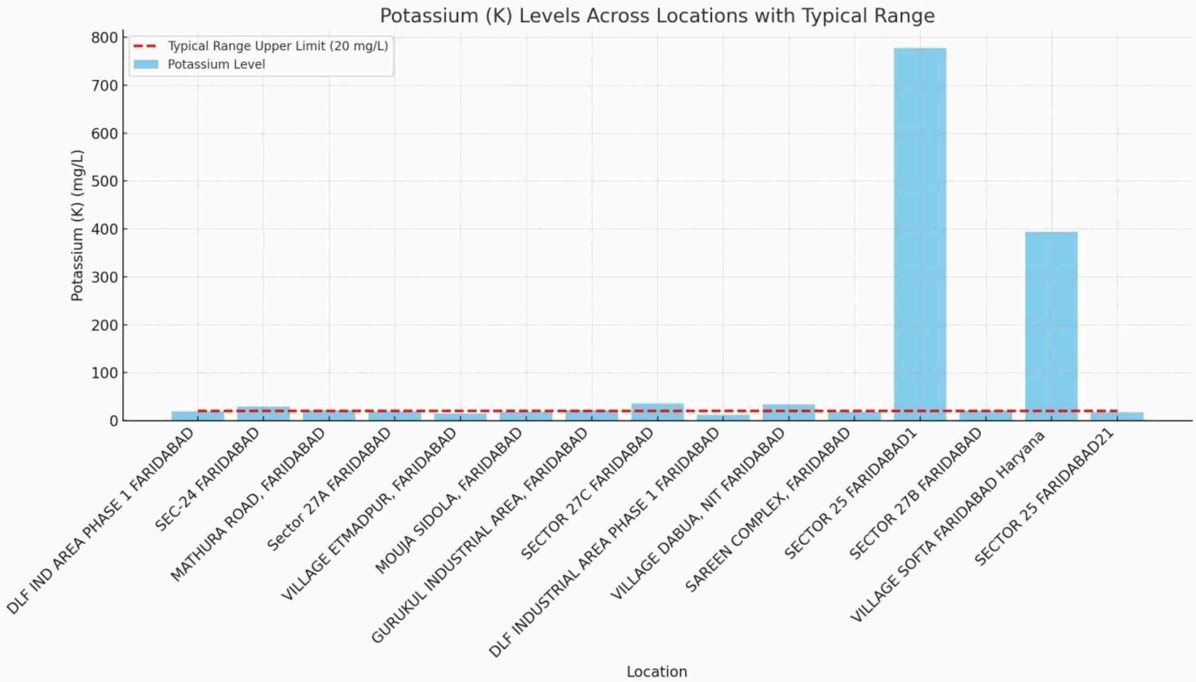


Figure 11 Potassium Levels across study site

4.1.10. CALCIUM (Ca)

The chart below shows the concentration of Calcium in mg/L at each location. Here, each bar represents a place, with the height showing the concentration in mg/L of Calcium in each place. The reasonable limit is this red dashed line, which is 75 mg/L, according to BIS standards, and the green line indicates the permissible limit of 200 mg/L. Most of the places indicate that the level of Calcium is excess over the desirable and permissible level. Here, the water will be more complex, and hence, it will cause scaling in the pipes. In this regard, it supports the inferential conclusion whereby water softening treatments should be administered to lower the level of Calcium in realization of good-quality waters that are going to be consumable either in homes or industries.

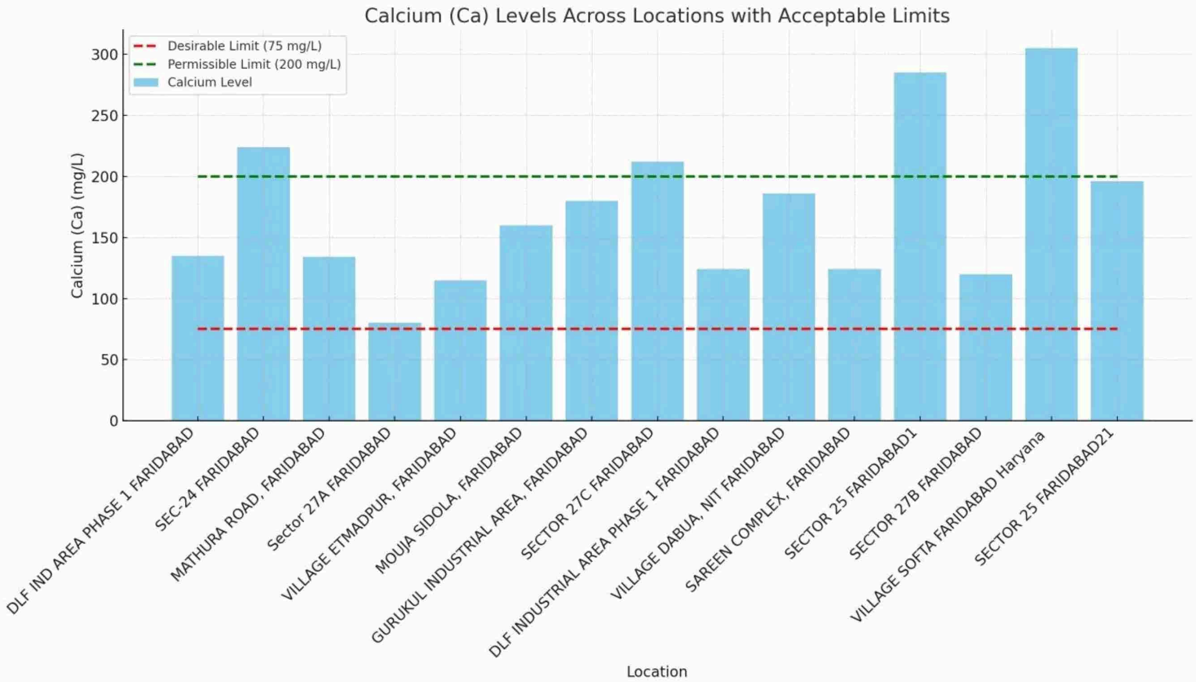
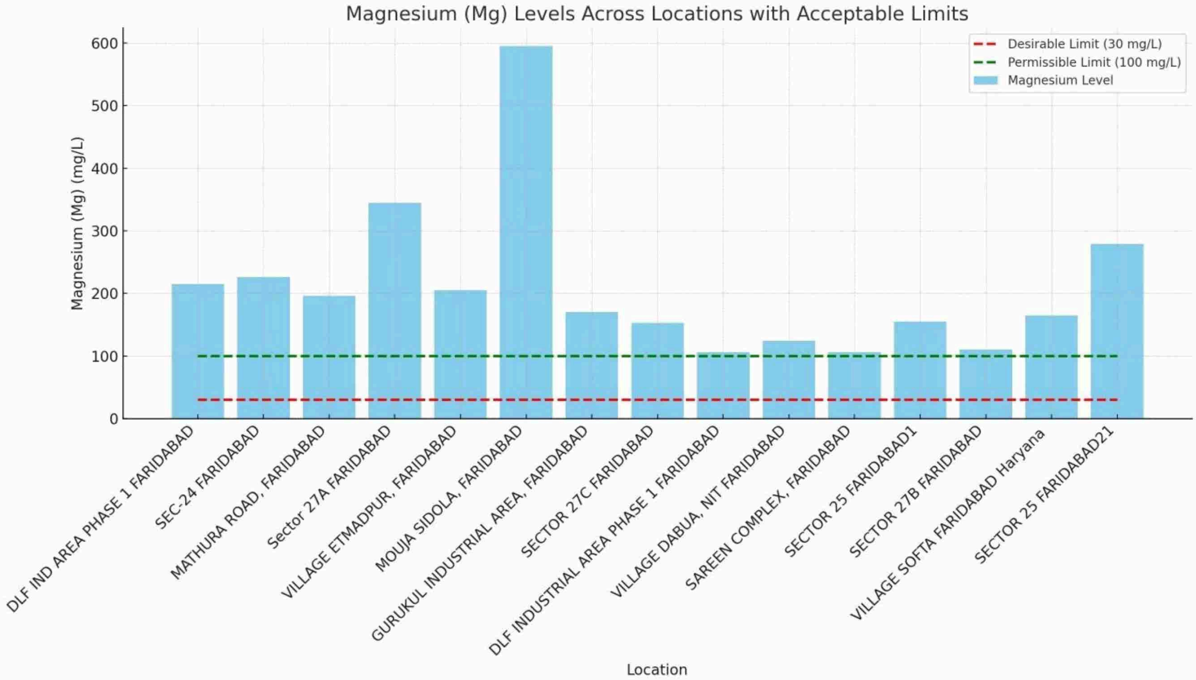


Figure 12 Calcium Levels across study site

4.1.11. MAGNESIUM (Mg)

The bar graph that shows the levels of Magnesium (Mg) in the samples of water collected from various places in Faridabad is as follows:. The y-axis reflects a location in height, for instance, the value of magnesium concentration in mg/L. The red dash in the line indicates the desirable limit according to the standards of BIS, i.e., 30 mg/L, while the green dashed line indicates the permissible limit, i.e., 100 mg/L. The graph indicates that the samples have a high magnesium concentration compared to the desired and permitted levels. This explains water hardness and enables water to act as a laxative agent. Water then becomes essential to be treated to make the levels of magnesium go low so that the water improves in terms of quality and safety and becomes very safe for consumption by human beings.



4.2.SUITABILITY FOR IRRIGATION

Table 3 summarizes the irrigation suitability parameters for various locations in Faridabad, including Percent Sodium (% Na), Soluble Sodium Percent (SSP), Sodium Absorption Ratio (SAR), Magnesium Hazard (MH), and Kelly's Ratio.

Table 3 Analysis of Irrigation parameters

LOCATIONS	%Na^+	SSP	SAR	MH	Kelly's Ratio
DLF IND AREA PHASE 1 FARIDABAD	22.39	18.18	6.20	61.43	0.23
SEC-24 FARIDABAD	21.60	16.55	6.33	50.22	0.21
MATHURA ROAD, FARIDABAD	23.26	18.14	6.07	59.39	0.24
Sector 27A FARIDABAD	16.50	12.77	4.46	81.18	0.15
VILLAGE ETMADPUR, FARIDABAD	26.77	23.34	8.06	64.06	0.32
MOUJA SIDOLA, FARIDABAD	7.70	5.50	2.32	78.81	0.06
GURUKUL INDUSTRIAL AREA, FARIDABAD	20.09	15.07	4.99	48.57	0.19
SECTOR 27C FARIDABAD	30.21	23.33	9.03	41.92	0.33
DLF INDUSTRIAL AREA PHASE 1 FARIDABAD	20.69	16.55	4.48	46.09	0.21

VILLAGE DABUA, NIT FARIDABAD	33.76	26.50	9.96	40.00	0.40
SAREEN COMPLEX, FARIDABAD	36.11	31.11	10.44	46.09	0.49
SECTOR 25 FARIDABAD1	77.88	38.81	52.05	35.23	1.75
SECTOR 27B FARIDABAD	27.90	21.32	6.34	47.83	0.30
VILLAGE SOFTA FARIDABAD Haryana	63.51	32.92	27.66	35.11	0.90
SECTOR 25 FARIDABAD21	40.18	38.04	19.60	58.74	0.64

According to irrigation water quality standards, % Na values below 60% indicate safe levels, while higher values suggest potential soil sodicity issues. Most locations have % Na below this threshold, except for SECTOR 25 FARIDABAD1 and VILLAGE SOFTA FARIDABAD Haryana, which exceed it. SSP values under 60% are considered suitable, and all locations meet this criterion, indicating general safety concerning soluble sodium. SAR values below 10 are ideal, while values between 10 and 18 are acceptable, and values above 18 are unsuitable for most crops. Most locations have SAR values below 10, except SECTOR 25 FARIDABAD1 and VILLAGE SOFTA FARIDABAD Haryana, indicating potential risks of reduced soil permeability and crop growth. MH values above 50% can adversely affect crop yield by competing with calcium and potassium uptake. Several locations exceed this limit, notably DLF IND AREA PHASE 1 FARIDABAD and SEC-24 FARIDABAD, suggesting possible magnesium-related issues. Kelly’s Ratio values below 1 are ideal, indicating safe sodium levels; however, SECTOR 25 FARIDABAD1 and VILLAGE SOFTA FARIDABAD Haryana exceed this threshold, further suggesting high sodium levels. Overall, while most locations in Faridabad have water that is generally suitable for irrigation, SECTOR 25 FARIDABAD1 and VILLAGE SOFTA FARIDABAD Haryana exhibit several parameters that exceed recommended limits, indicating the need for water treatment or alternative management practices to ensure sustainable Irrigation Suitability Criteria of Different Places Under Faridabad Location Based on Percent Sodium (% Na), Soluble Sodium Percent (SSP), Sodium Absorption Ratio (SAR), Magnesium Hazard (MH) and Kelly's Ratio The table below summarizes the irrigation suitability criteria of different places under the Faridabad location based on the percent sodium, soluble sodium percent, sodium absorption ratio, magnesium hazard, and Kelly's ratio. Of the significant characteristics of quality of water for irrigation, % Na values that are less than 60% are safe, whereas those above that are. About the % Na, all locations except SECTOR 25 FARIDABAD1 and VILLAGE SOFTA FARIDABAD of Haryana have values above the critical level. All these locations have SSP values less than

60%, which fall under the safe category. The areas are generally safe in comparison to soluble Na. SAR values less than ten are excellent; in-between 10 and 18, it is considered safe, and above SAR values are unsuited for most crops. But in most places, the SAR values are less than 10, except SECTOR 25 FARIDABAD1 and VILLAGE SOFTA FARIDABAD, Haryana. It is also a mirror of the potential threat in terms of a decrease in the permeability of soil and growth of crops. The values greater than 50% of MH create harmful effects on the yield of crops because, at this value, Mg starts competing with calcium and potassium in crop uptake. Several places cross this critical limit, including DLF IND AREA PHASE 1 FARIDABAD and SEC-24 FARIDABAD. This suggests the threat of Mg-related issues. Exit now, and only the values of Kelly's Ratio below 1 are perfect and mean the levels are safe. Much more in SECTOR 25 FARIDABAD1 and VILLAGE SOFTA FARIDABAD Haryana, where the values exceed what is set as a threshold further suggests high sodium levels. In most of the locations, overall water is found suitable for irrigation use, particularly with the factorial 25 Faridabad 1. At the same time, quite a few parameters exceed the recommended limits, so the water either needs treatment or some alternative management practices in a sustainable irrigation process. irrigation.

4.2.1. PERCENT SODIUM (% Na^+):

From the above graph, it can be observed relatively clearly that the Percent Sodium (% Na) in various sites in Faridabad is above the allowable limit of 60%. Most of the locations had sodium contents below this threshold, showing that sodium is at a safe level for irrigation and situations in which soil sodicity is not a problem. However, these two locations, SECTOR 25 FARIDABAD1 and VILLAGE SOFTA, HARYANA, are highly above this limit, showing potential risks for structural degradation and possible reduction of permeability, which could result in an overall negative influence on crop growth and soil health status.

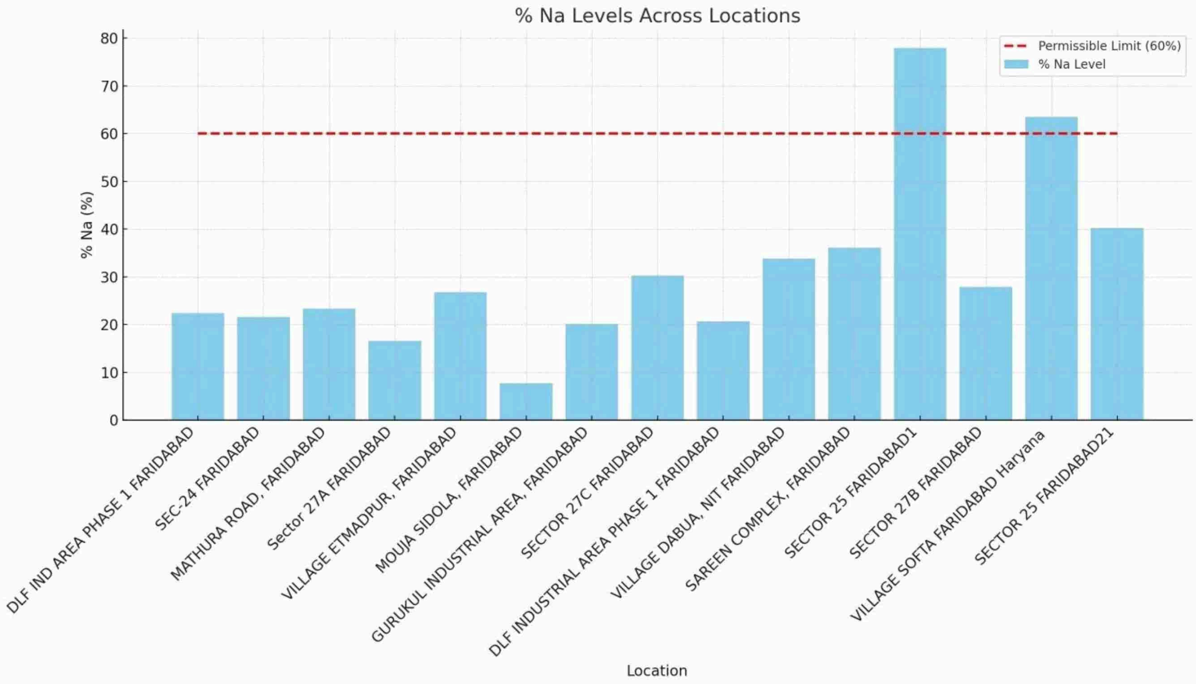


Figure 13 Percent Sodium across study site

4.2.2. SOLUBLE SODIUM PERCENT (SSP):

The bar graph for Soluble Sodium Percent (SSP) depicts that the values are well below the critical level for all the locations. Water from these locations can be judged to be generally safe for irrigation from a soluble sodium point of view, as the values are less than 60. The lower values of SSP mean lower chances of dispersion of the soil and structural problems, if any, induced by sodium. Low SSP values imply better soil health and crop productivity. The bar graph on the values of SAR shows very nicely that most of the values are way below 10. This is well brought out by the red dashes of lines that indicate the limit of desirability and those below the 18 green dashes of lines, which are then indicated as the permissible limit. Shows very great suitability of different areas for irrigation.

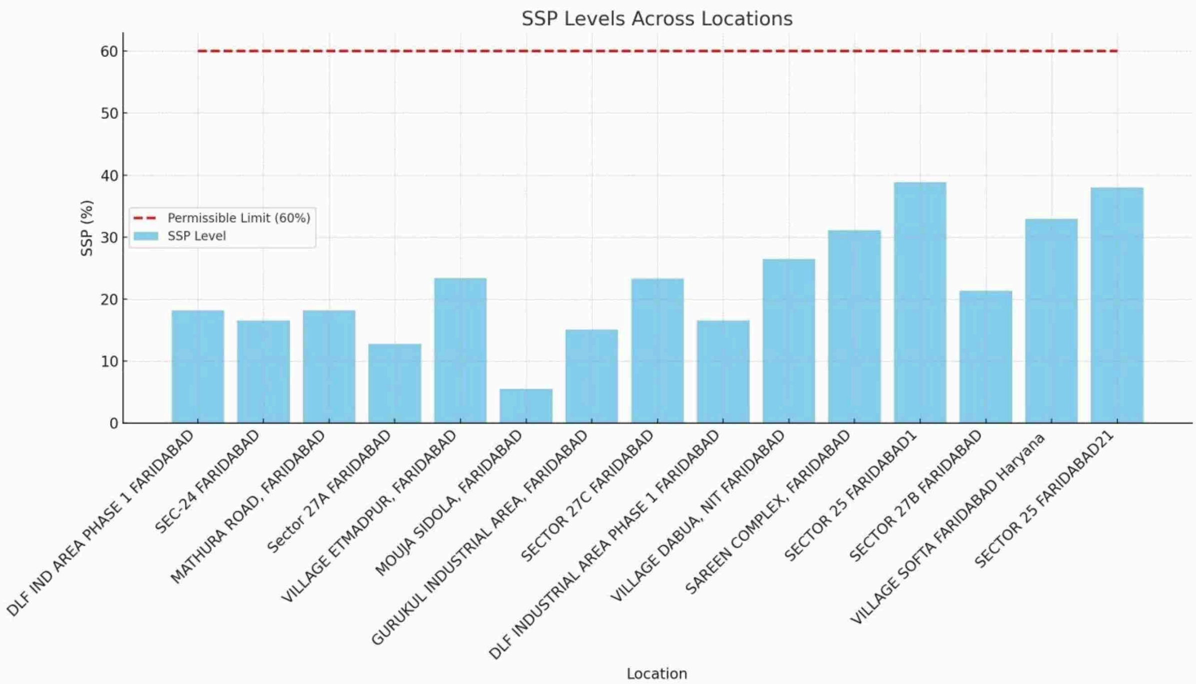


Figure 14 Soluble Sodium Percent

4.2.3. SODIUM ABSORPTION RATIO (SAR):

However, SECTOR 25 FARIDABAD1 and VILLAGE SOFTA FARIDABAD2 in the State of Haryana have values much above even permissible limits, with SAR values much higher than 18. This situation presents a high possibility of reducing soil permeability and causing toxic hazards to crops sensitive to salinity. Corrective measures, therefore, like gypsum application or blending with better quality water, are called for. Graph The level is shown to be 50% at the limit, by red dots, for percentage magnesium levels in the hazardous area. On the line above, at different places, DLF IND AREA PHASE 1 FARIDABAD and SEC-24 FARIDABAD, the level is very high. This also would indicate that high magnesium content does not mean a good yield of crops. Excess magnesium can compete with calcium and potassium, throwing out the availabilities of those elements and spoiling soil structure stability. This calls for the factor that there should be careful management and possible soil amendment.

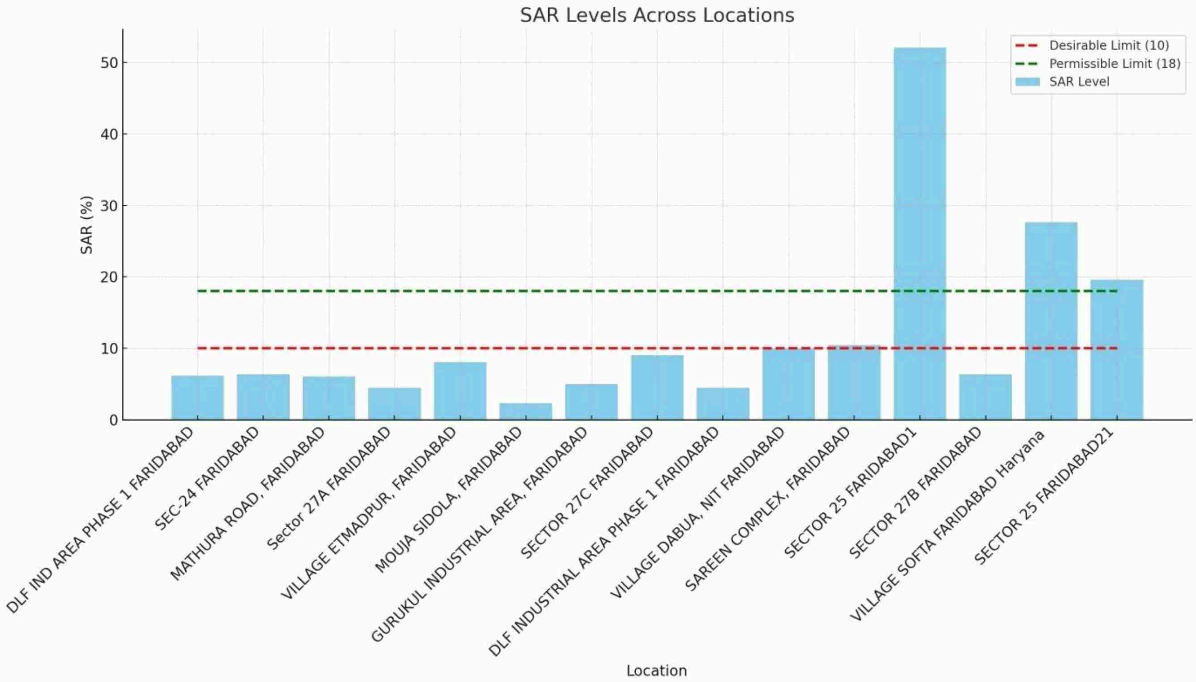


Figure 15 Sodium Absorption Ratio across study site

4.2.4. MAGNESIUM HAZARD (MH):

The Magnesium Hazard (MH) bar chart displays the levels across different sites, with a red dashed line marking the permissible level at 50%. Many of the sites are reported above that level. Prominent tendencies among them are DLF IND AREA PHASE 1 FARIDABAD and SEC-24 FARIDABAD, which might harm the yield. It contains, however a small percentage of magnesium that is too high, therefore over-competing for uptake by plants of Ca and K and causing nutrient imbalance; this, in turn, leads to a reduction of structural soil stability and should be handled with care.

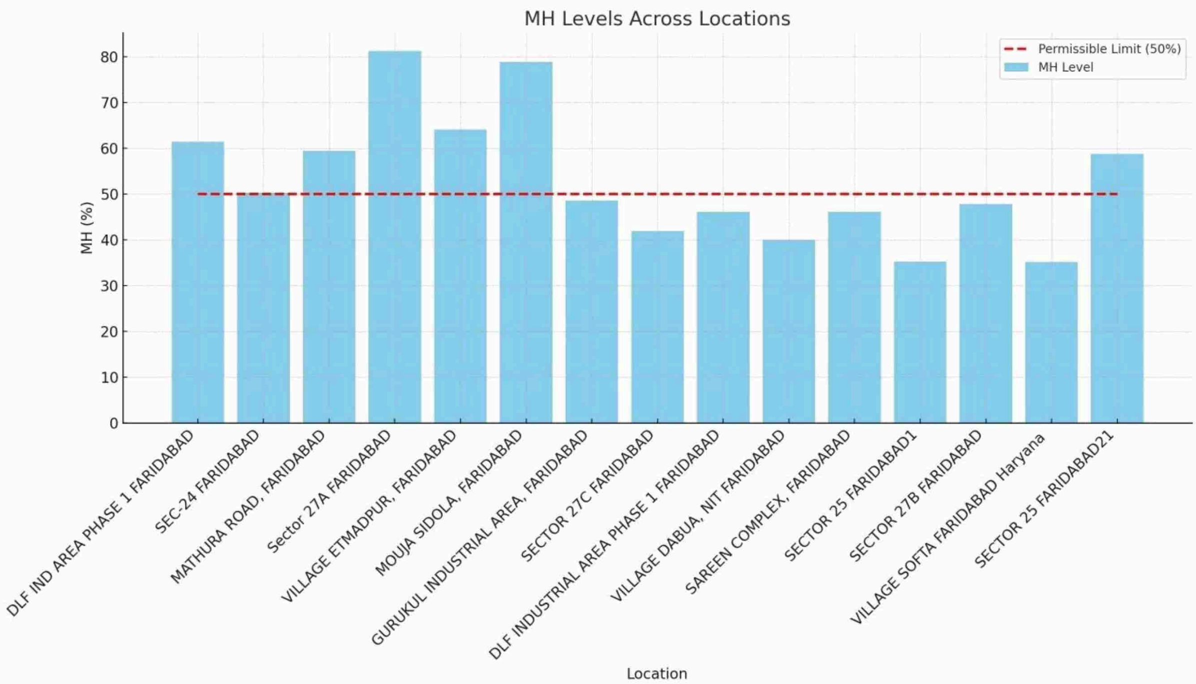


Figure 16 MH Levels across study site

4.2.5. KELLY'S RATIO:

The graph below illustrates Kelly's Ratio and problem sets of values at various locations, in which the red dashed line shows the permissible ceiling of 1. At nearly all places, it is below 1, which specifies the sodium levels are reasonably suitable for applying water for irrigation, and it has exceeded the permissible ceiling of 1 at only two locations: SECTOR 25 FARIDABAD1 and VILLAGE SOFTA FARIDABAD, Haryana, placed far below the 1 line, which is indicating overburdening of sodium to calcium and magnesium. If left unattended, this may ultimately lead to sodicity of soil with disastrous effects on the structure and permeability of the soil. This may require the use of soil conditioners or the use of alternative water sources.

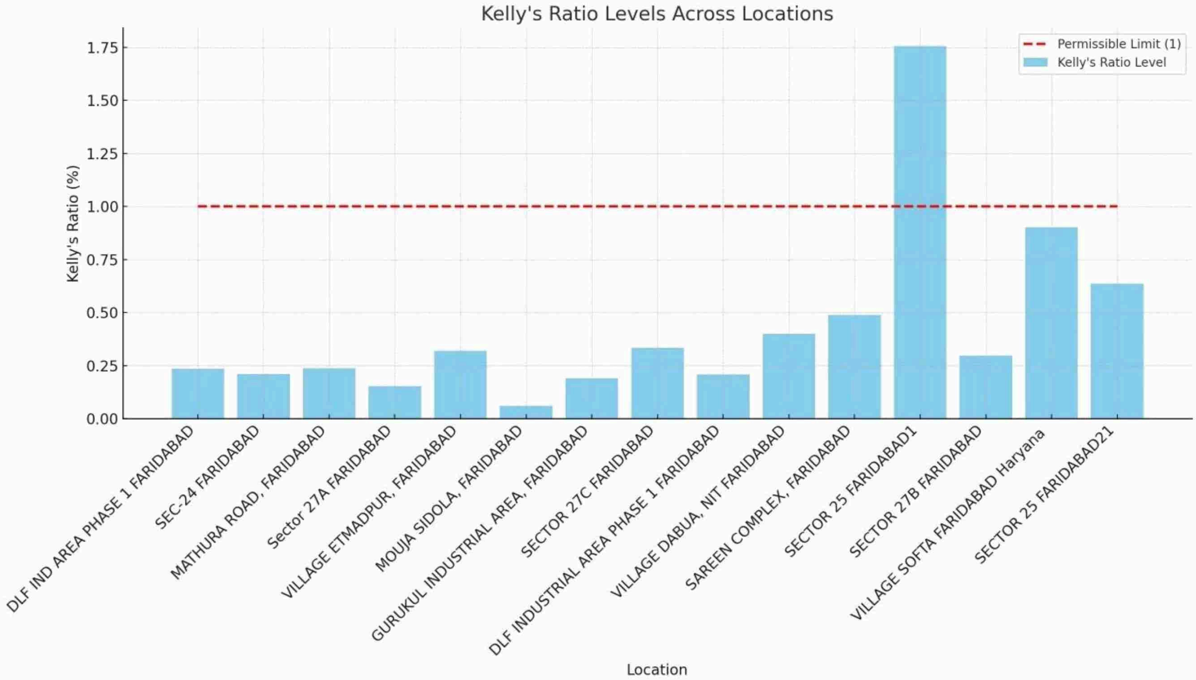


Figure 17 Kelly's Ratio Levels across study site

CONCLUSION

The area of water quality management challenges the quality of groundwater. Faridabad contains highly distributed uneven concentrations of various important water quality parameters in a tested sample, such as pH, TDS (Total Dissolved Solids), total hardness, Cl (chloride), NO3 (nitrate), SO4 (sulphate), Na (sodium), K (potassium), Ca (calcium), and Mg (magnesium) in water at various locations. All the sampled locations generally indicate permissible pH levels, neither acidic nor alkaline. However, high values of TDS, total hardness, and chloride are rather pervasive. High values of TDS are essential not only due to long-term health risks but also to imparting an unacceptable taste to water. Similarly, high values of total hardness and chloride, though within permissible limits, might increase scaling in the equipment's plumbing and can result in salinity in the water. Though nitrate levels are within acceptable values, a low hazard is posed for immediate health problems; nevertheless, the high sulphate, sodium, and potassium concentration in the whole area give a flashing signal regarding soil salinity and its effect on crop health. High Mg levels at some sites indicate a higher potential for adverse agricultural impacts, such as nutrient imbalances that can affect growth and yield. Therefore, such a detailed study reflects the pressing need for successfully managing and treatment strategies of ground waters to meet the challenged water quality from Faridabad. Periodical monitoring of water is essential to screen quality identify sources of contamination, and reduce possible impacts through timely remediation. The scheme of water treatment solutions taken up could include overall groundwater quality improvement, reverse osmosis for TDS reduction, and removal of hardness by ion exchange methods. Further, public awareness campaigns that should stress responsible use of water resources and preservation of water quality can facilitate the inculcation of community involvement in conservation. A second mobilization should be by policymakers, through developing and applying water quality standards with rigor, in the process helping ensure the public health and that agriculture remains sustainable. The groundwater quality-related challenges need to be taken into account meaningfully by adopting a multi-faceted approach involving technological interventions, regulatory measures, and community engagement. This will ensure healthy assurance and safety of the residents and long-term sustenance of its agricultural activities.

REFERENCES

Adimalla, N., & Venkatayogi, S. (2017). Hydrogeochemical assessment of groundwater quality of Gooty area, Andhra Pradesh, South India. Applied Water Science, 7(7), 4135-4150.

Adimalla, N., & Venkatayogi, S. (2018). Geochemical characterization and evaluation of groundwater suitability for domestic and agricultural purposes in Central Telangana, India. Groundwater for Sustainable Development, 6, 43-55.

Adimalla, N., Li, P., & Venkatayogi, S. (2018). Hydrogeochemical evaluation of groundwater quality for drinking and irrigation purposes and integrated interpretation with water quality index studies. Environmental Processes, 5, 363-383.

Adimalla, N., Li, P., & Venkatayogi, S. (2019). Hydrochemical characterization and quality assessment of groundwater from semi-arid region of South India. Human and Ecological Risk Assessment: An International Journal, 25(5), 1107-1123.

Adimalla, N., Taloor, A. K., & Li, P. (2020). Groundwater quality assessment using geochemical and statistical techniques in the semi-arid region of Medak, Telangana State, South India. Water, 12(1), 23.

Azizullah, A., Khattak, M. N. K., Richter, P., & Häder, D.-P. (2011). Water pollution in Pakistan and its impact on public health—a review. Environment International, 37(2), 479-497.

Bajwa, B. S., Kumar, S., Singh, S., & Kumar, M. (2017). Concentration of heavy metals in groundwater and associated health risks in South-Western Punjab, India. Environmental Earth Sciences, 76(14), 475.

Bhushan, S. K. (2000). The Malani Igneous Suite and its relation to crustal evolution in northwestern India. Memoirs of the Geological Society of India, 42, 1-25.

Chalkiadaki, O., Paraskevas, M., & Botsaris, G. (2014). Heavy metal contamination in soil and water: A review of sources, effects, and control strategies. Environmental Monitoring and Assessment, 186(8), 5167-5176.

Chetan, K., & Ahada, C. P. (2017). Evaluation of groundwater quality and its suitability for drinking and irrigation in Malwa region, Punjab, India. Environmental Earth Sciences, 76(4), 141.

Chidambaram, S., Karmegam, U., Prasanna, M. V., & Thivya, C. (2011). A study on the chemical characteristics of groundwater in the coastal aquifers of Kadaladi, Ramanathapuram district, Tamil Nadu, India. Indian Journal of Science and Technology, 4(4), 410-415.

Dessert, C., Dupré, B., Gaillardet, J., François, L. M., & Allègre, C. J. (2003). Basalt weathering laws and the impact of basalt weathering on the global carbon cycle. Chemical Geology, 202(3-4), 257-273.

Dişli, E. (2017). Hydrogeochemical characteristics of groundwater from eastern Antalya basin, Turkey. Environmental Earth Sciences, 76(8), 305.

Eaton, F. M. (1950). Significance of carbonate in irrigation waters. Soil Science, 69(2), 123-133.

Eby, G. N., & Kochhar, N. (1992). Petrogenesis of the Malani igneous suite, North Peninsular India. Lithos, 28(3-4), 101-117.

Faten, B. R., Ahmed, A. E., & Mehdi, A. (2016). Water quality index and GIS approach for assessing groundwater quality in Al-Rahba area, northeastern Tunisia. Arabian Journal of Geosciences, 9(3), 188.

Finlow-Bates, T., & Stumpfl, E. F. (1981). The behaviour of some platinum metals in hydrothermal processes. Mineralium Deposita, 16(3), 309-328.

Gupta, S., & Deshpande, R. D. (2015). Groundwater quality assessment using water quality index (WQI) in Varuna river basin, India. Asian Journal of Water, Environment and Pollution, 12(1), 55-62.

Haritash, A. K., & Singh, B. (2017). Spatial distribution of uranium and other heavy metals in groundwater of Faridabad district, Haryana, India. Journal of Radioanalytical and Nuclear Chemistry, 311(1), 205-211.

Haritash, A. K., & Singhal, D. (2017). Evaluation of groundwater quality and health risk due to nitrate contamination in a semi-arid region of Haryana, India. Human and Ecological Risk Assessment: An International Journal, 23(5), 1080-1092.

Hedenquist, J. W., & Arribas, A. (1999). Epithermal gold deposits: Styles, characteristics, and exploration. Society of Economic Geologists, Special Publication, 6, 157-170.

Hedenquist, J. W., & Richards, J. P. (1998). The influence of geochemical environment on the epithermal gold deposits: A review. Ore Geology Reviews, 13(1-5), 417-426.

Jasrotia, A. S., Kumar, A., & Kumar, R. (2018). Assessment of groundwater quality for drinking and irrigation purposes using hydrochemical studies in a semi-arid region of Jammu and Kashmir, India. Environmental Earth Sciences, 77(15), 559.

Karakaya, N., & Karakaya, M. Ç. (2007). Geochemistry and origin of the altered volcanic rocks from the Kızıldağ region, Eastern Pontides, NE Turkey. Journal of Asian Earth Sciences, 29(2-3), 366-379.

Kochhar, N. (1984). The geology of Tosham Ring Complex, Haryana, India. Journal of the Geological Society of India, 25(9), 542-552.

Krishnan, K. S., John, D., & Singh, S. (2017). Groundwater contamination in the industrial areas of India: A review. Environmental Earth Sciences, 76(14), 473.

Kumar, A., & Singh, R. (2010). Hydrogeochemical assessment of groundwater in the Delhi National Capital Region, India. Environmental Monitoring and Assessment, 163(1-4), 403-415.

Kumar, A., Singh, A., & Jat, H. (2019). Hydrogeochemical characterization of groundwater in parts of Jodhpur, Rajasthan, India. Environmental Earth Sciences, 78(6), 184.

Kumar, A., & Singh, R. (2018). Assessment of groundwater quality in Delhi NCR using multivariate statistical techniques. Environmental Monitoring and Assessment, 190(4), 239.

Lerouge, C., Dubois, M., & Gauthier-Lafaye, F. (2004). Geochemical constraints from fluid inclusions on the genesis of the hydrothermal uranium ore-deposit at Cigar Lake, Saskatchewan, Canada. Economic Geology, 99(8), 1561-1575.

Li, P., Qian, H., & Wu, J. (2016). Hydrochemical evaluation of groundwater in the Guanzhong Basin, China: Spatial distribution and sources of contamination. Environmental Earth Sciences, 75(3), 239.

Li, P., Wu, J., & Qian, H. (2016). Hydrogeochemistry and quality assessment of groundwater in and around a mountainous tourist town of China. Water and Environment Journal, 30(4), 385-393.

MacLean, W. H., & Kranidiotis, P. (1987). Immobile elements as monitors of mass transfer in hydrothermal alteration: Phelps Dodge massive sulfide deposit, Matagami, Quebec. Economic Geology, 82(4), 951-962.

Muhammad, S., Shah, M. T., & Khan, S. (2017). Heavy metal contamination in groundwater and its human health risks in Swat, Pakistan. Environmental Science and Pollution Research, 24(27), 27465-27475.

Nickson, R., McArthur, J., Shrestha, B., Kyaw-Myint, T. O., & Lowry, D. (2005). Arsenic and other drinking water quality issues, Muzaffargarh District, Pakistan. Applied Geochemistry, 20(1), 55-68.

Pareek, H. S. (1981). Geology and evolution of the Malani Igneous Suite: A review. Geological Society of America Bulletin, 92(8), 666-674.

Rajesh, R., Manikandan, S. N., & Magesh, N. S. (2012). Hydrochemical characteristics and groundwater quality assessment in the Tirupur region of Tamil Nadu, India. Environmental Monitoring and Assessment, 184(6), 3861-3872.

Raju, N. J., Ram, P., & Dey, S. (2008). Groundwater quality in the lower Varuna River Basin, Varanasi district, Uttar Pradesh. Journal of the Geological Society of India, 71(1), 191-201.

Rebolledo, M. P., Ramírez, D. A., & Vidal, R. M. (2016). Assessment of nitrate contamination in groundwater in Chile using geographic information systems. Environmental Earth Sciences, 75(4), 338.

Sadat-Noori, M., Ebrahimi, K., & Liaghat, A. (2014). Groundwater quality assessment using GIS and water quality index in a semi-arid area, Iran. Environmental Earth Sciences, 71(9), 3827-3843.

Sharma, S., & Kansal, A. (2011). Water quality analysis of River Yamuna using water quality index in the national capital territory, India (2000-2009). Applied Water Science, 1(3-4), 147-157.

Shah, T., DebRoy, A., Qureshi, A. S., & Wang, J. (2003). Sustaining Asia's groundwater boom: An overview of issues and evidence. Natural Resources Forum, 27(2), 130-141.

Singh, R., & Kumar, R. (2016). Groundwater quality analysis for drinking and irrigation in Moradabad district, Western Uttar Pradesh, India. Hydrological Sciences Journal, 61(1), 174-182.

Slaveykova, V. I., & Karadjova, I. B. (2018). Trace metals in waters and sediments of the Danube River: An overview of contaminant sources, potential risks, and mitigation options. Environmental Science and Pollution Research, 25(8), 7309-7320.

Subba Rao, N., & Surya Rao, P. (2012). Spatial distribution of groundwater quality parameters in the Southern part of India. Journal of Geological Society of India, 79(2), 123-136.

Suthar, S., Bishnoi, P., Singh, S., Mutiyar, P. K., Nema, A. K., & Patil, N. S. (2009). Nitrate contamination in groundwater of some rural areas of Rajasthan, India. Journal of Hazardous Materials, 171(1-3), 189-199.

Vahab, M., Zarei, M., & Khodaei, M. (2015). Hydrochemical assessment of groundwater quality for drinking and agricultural purposes in Anar Plain, southeastern Iran. Environmental Earth Sciences, 74(8), 6281-6296.